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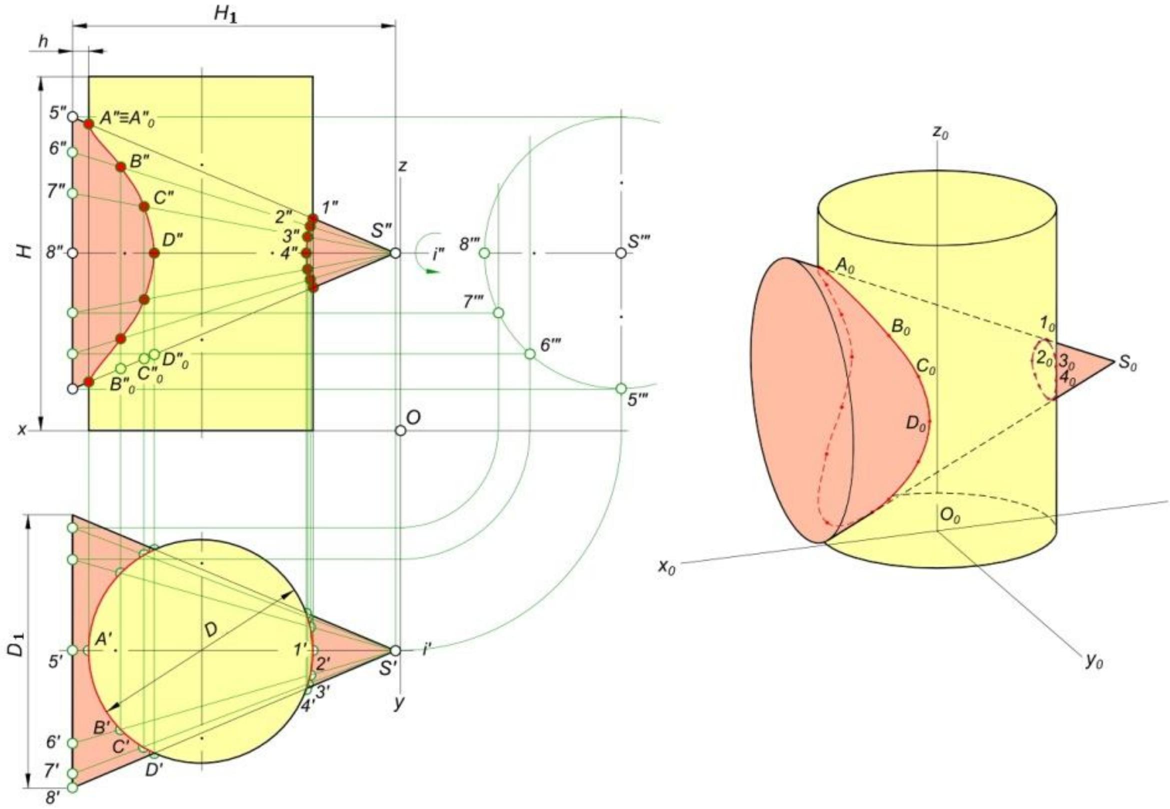
O. M. BEKETOV NATIONAL UNIVERSITY
of URBAN ECONOMY in KHARKIV

M. Liubchenko

ENGINEERING and COMPUTER GRAPHICS

LECTURES

(for 1-st year full-time foreign students education level bachelor, specialty 192 – Construction and Civil Engineering)



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INTRODUCTION

Engineering and Computer Graphics is a discipline that requires of graphics knowledge's of students of all specialties. Design and construction, understanding the principle of technological depicted product are closely associated with images: drawings, paintings, sketches.

The Engineering and Computer Graphics discipline poses a lot of important engineering tasks and problems. The course of Engineering and Computer Graphics should provide different drawing skills and representation skills of technical ideas by drawing.

The main purpose of the discipline is acquisition of knowledge and necessary skills for students to perform and read technical drawings, sketches, implementation details and working with documents.

Lectures in the discipline Engineering and Computer Graphics are designed for 1-st year full-time foreign students, specialty 192 – Construction and Civil Engineering.

Engineering activities are related to the design, manufacture and operation of machines, mechanisms, various structures and other spatial objects.

Therefore, for a successful practical activity, the engineer must have a well-developed spatial imagination and have the skills to draw. It is the main document for solving engineering problems and contains all necessary information for this purpose: image of the object, its size and material of it. Obviously, all this information, including the image of the object, should be drawn according to general rules.

LECTURE 1 PROJECTION

1.1 Definitions

The following terms are used repeatedly throughout this text, and therefore a thorough understanding of their meaning is imperative for the proper study of Descriptive Geometry.

Orthographic Projection – parallel lines of sight at 90° to an image plane.

Horizontal plane – an image plane, all points of which are at the same elevation. The top (plan view) is determined by the projection of the object on this plane.

Frontal plane – an image plane at 90° to the horizontal and profile planes. The front elevation view is determined by the projection of the object on this plane. The lines of sight for this frontal plane are horizontal and are therefore perpendicular to it.

Profile plane – an image plane at right angles to both the horizontal and frontal planes. The right and left side elevation views are determined by the projection of the object on this plane. The lines of sight for this profile plane are horizontal and are therefore perpendicular to it.

Folding line or *Reference plane line* – the line made by the intersection of two image planes. It is designed as a long line, two short dashes and then another long line.

Elevation view – any orthographic view for which the lines of sight are horizontal and perpendicular to the image plane. It may be projected from a plan view, other elevation views, or from inclined views. Any view projected from the plan view must be an elevation view.

Inclined view – any orthographic view for which the lines of sight are neither horizontal nor vertical. It may be projected from an elevation view or other inclined views, but never from a plan view.

Line – the path of a moving point.

Straight line – the path of a moving point proceeding constantly in the same direction. A line having a definite length is determined by its extremities. However, any two points on the line may be chosen for the purpose of locating the entire line in another view. The end view of a line is a point which represents all points on the line.

Level line – a line which is parallel to the horizontal image plane and which therefore has all points on the line at the same elevation. It will appear in its true length in the plan view.

Frontal line – a line which lies parallel to the frontal image plane. The line must show in its true length in the front view even though it may be level, vertical, or inclined.

Profile line – an inclined line which lies parallel to the profile image plane. The line must show in its true length in the profile view.

Vertical line – a line which is perpendicular to a level plane. It will appear in its true length in any elevation view.

Inclined line – a line neither vertical nor horizontal but which may appear in its true length in either the frontal or profile planes. It cannot appear in its true length in the plan view.

Oblique line – a line inclined to all three principal planes. It cannot appear in its true length in any of the three principal planes.

Contour line – a straight or curved line used on topographical drawings which locates a series of points at the same elevation. Therefore, a contour line is a level line.

Normal view of a *Line or plane* – the view which shows the true length of the line or the true size of the plane. A normal view of a plane shows the true size of any angle on the plane and the true length of any line which lies on the plane.

Slope of a line – tangent of the angle that the line makes with a horizontal plane. Two conditions must be met in order to determine the slope of a line. First, the line must be shown in an elevation view; secondly, the line must appear in its true length in this elevation view. Note: An inclined view may show the true length of a line but it cannot show the true slope of the line because a horizontal plane does not appear as an edge in an inclined view.

1.2 First angle and third angle projection

Orthographic projection is the solution to the biggest problem that a draughtsperson has to solve – how to draw, with sufficient clarity, a three-dimensional object on a two-dimensional plane. The drawing must show quite clearly the detailed outlines of all the faces and these outlines must be fully dimensioned. If the object is very simple, this may be achieved with a freehand sketch. A less simple object could be drawn in either isometric or oblique projections, although both these systems have their disadvantages. Circles and curves are difficult to draw in either system and neither shows more than three sides of an object in any one view. Orthographic projection, because of its flexibility in allowing any number of views of the same object, has none of these drawbacks.

Orthographic projection has two forms: first angle and third angle; we shall discuss both. Traditionally, British industry has used first angle while the United States of America and, more recently, the continental countries used the third angle system.

There is no doubt that British industry is rapidly changing to the third angle system and, although this will take some years to complete, third angle will eventually be the national and international standard of orthographic projection.

Figure 1.1 shows a stepped block suspended between two planes. A plane is a perfectly flat surface. In this case one of the planes is horizontal and the other is vertical. The view looking on the top of the block is drawn directly above the block on the horizontal plane (HP). The view looking on the side of the block is drawn directly in line with the block on the vertical (frontal) plane (VP or FP). If you now take away the stepped block and, imagining that the two planes are hinged, fold back the HP so that it lines up with the VP, you are left with two drawings of the block. One is a view looking on the top of the block and this is directly above another view looking on the side of the block. These two views are called ***elevations***.

Figure 1.1 shows the block in first angle orthographic projection. The same block is drawn in Figure 1.2 in third angle orthographic projection. You still have a VP and a HP but they are arranged differently. The block is suspended between the two planes and the view of the top of the block is drawn on the HP and the view of the side is drawn on the VP. Again, imagining that the planes are hinged, the HP is folded down so that the planes are in line. This result in the drawing of the side of the block being directly above the drawing of the top of the block (compare this with the third angle drawings).

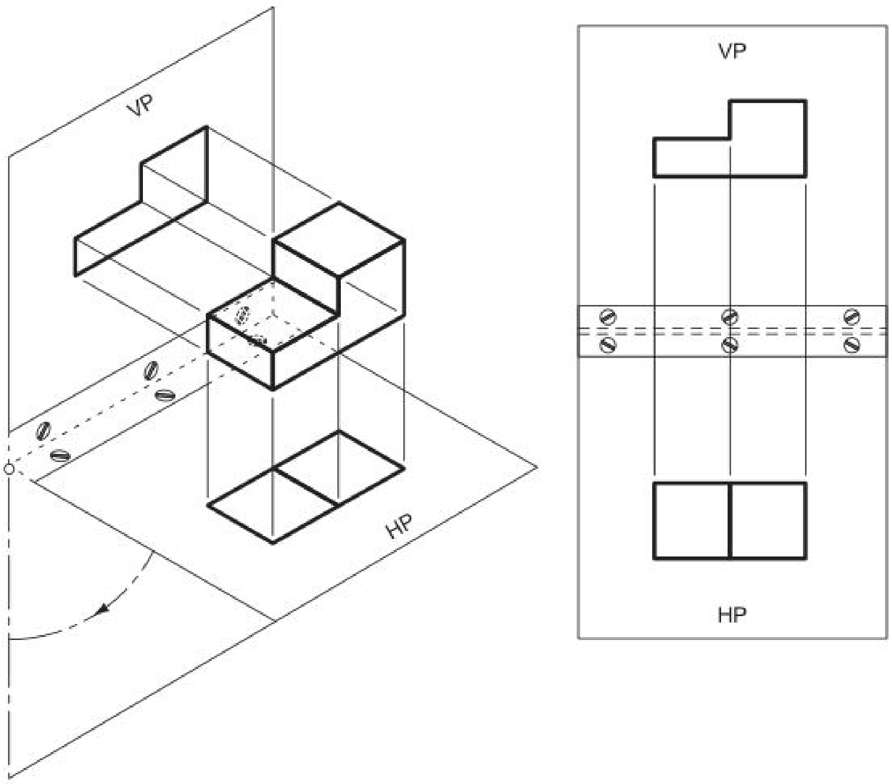


Figure 1.1 – First angle orthographic projection

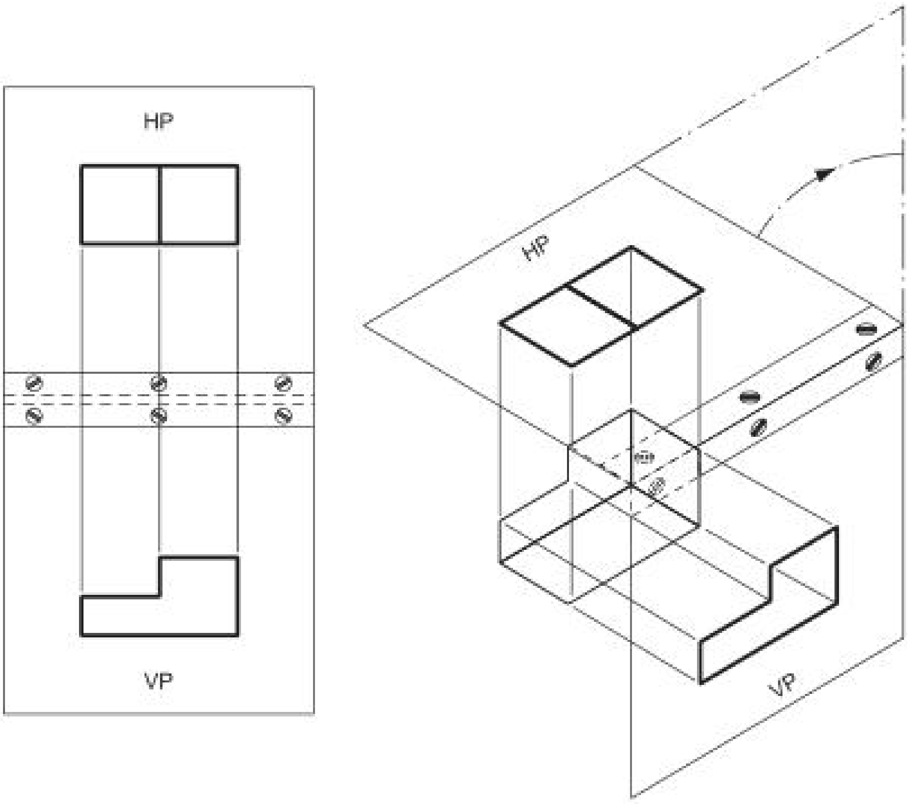


Figure 1.2 – Third angle orthographic projection

The reason why these two systems are called first and third angle is shown in Figure 1.3. If the HP and the VP intersect as shown, it produces four quadrants. The first quadrant, or first angle, is the top right and the third is the bottom left. If the block is suspended between the VP and the HP in the first and third angles, you can see how the views are projected onto the two planes.

So far we have obtained only two views of the block, one on the VP and one on the HP. With a complicated block this may not be enough. This problem is easily solved by introducing another plane. In this case it is a VP and it will show a view of the end of the block and so, to distinguish it from the other VP, it is called the end vertical plane (EVP), and the original vertical plane is called the front vertical plane (FVP).

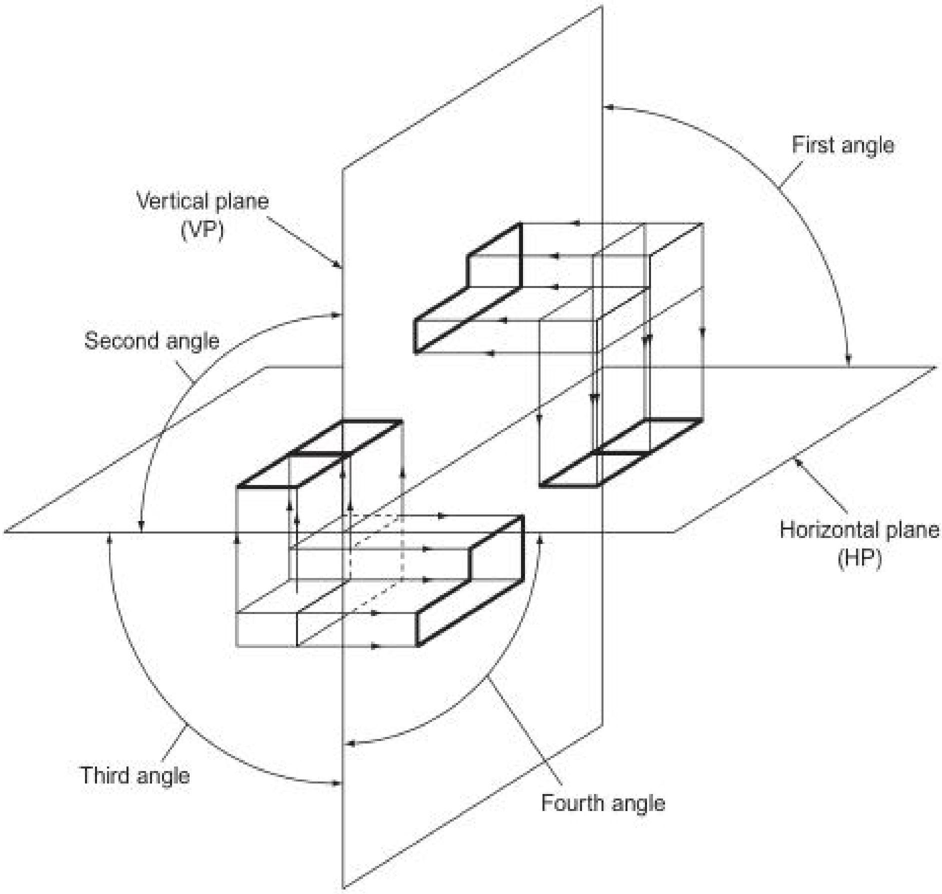


Figure 1.3 – Relative positions of first and third angle projections

The EVP is hinged to the FVP and when the views have been projected onto their planes, the three planes are unfolded and three views of the block are shown in Figure 1.4.

The drawing on the FVP is called the front elevation (FE), the drawing on the EVP is called the end elevation (EE) and the drawing on the HP is called the plan. All three views are linked together: the plan is directly above the FE; the EE is horizontally in line with the FE; and the plan and the EE can be linked by drawing 45° projection lines. This is why orthographic projection is so important; it is not just because several views of the same object can be drawn, it is because the views are linked together.

Figure 1.4 shows three views of the block drawn in third angle; Figure 1.5 shows three views of the same block drawn in first angle.

In this case the FE is above the plan and to the left of the EE (compare this with third angle). Once again, the EE and the plan can be linked by projection lines drawn at 45°.

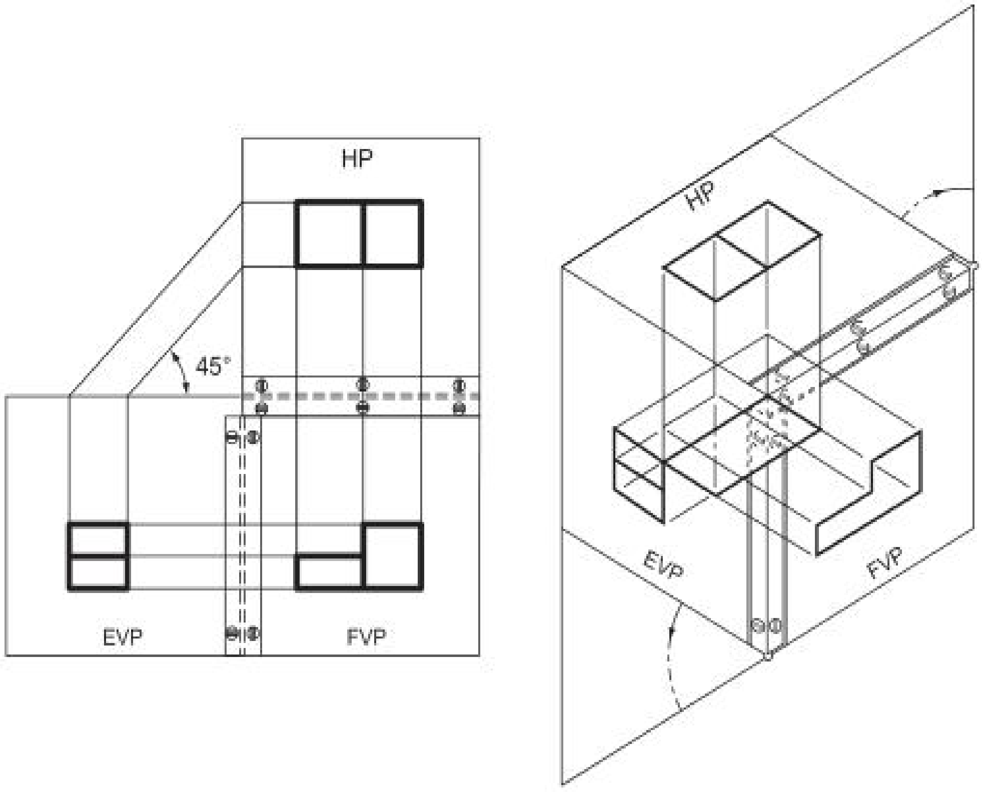


Figure 1.4 – Third angle orthographic projection

The system of suspending the block between three planes and projecting views of the block onto these planes is the basic principle of orthographic projection and must be completely understood if one wishes to study this type of projection any further.

The following system is somewhat easier to understand and will meet most of the reader's needs.

Figure 1.6 shows the same shaped block drawn in third angle projection. First, draw the view obtained by looking along the arrow marked FE. This gives you the FE. Now look along the arrow marked EE $_1$ (which points from the left) and draw what you see to the left of the FE. This gives you an EE. Now look along the arrow marked EE $_2$ (which points from the right) and draw what you see to the right of the FE. This gives you another EE. Now look down onto the block, along the arrow marked «plan» and draw what you see above the FE. This gives the plan and its exact position is determined by drawing lines from one of the EE at 45° .

Note that with third angle projection, what you see from the left you draw on the left, what you see from the right you draw on the right and what you see from above you draw above.

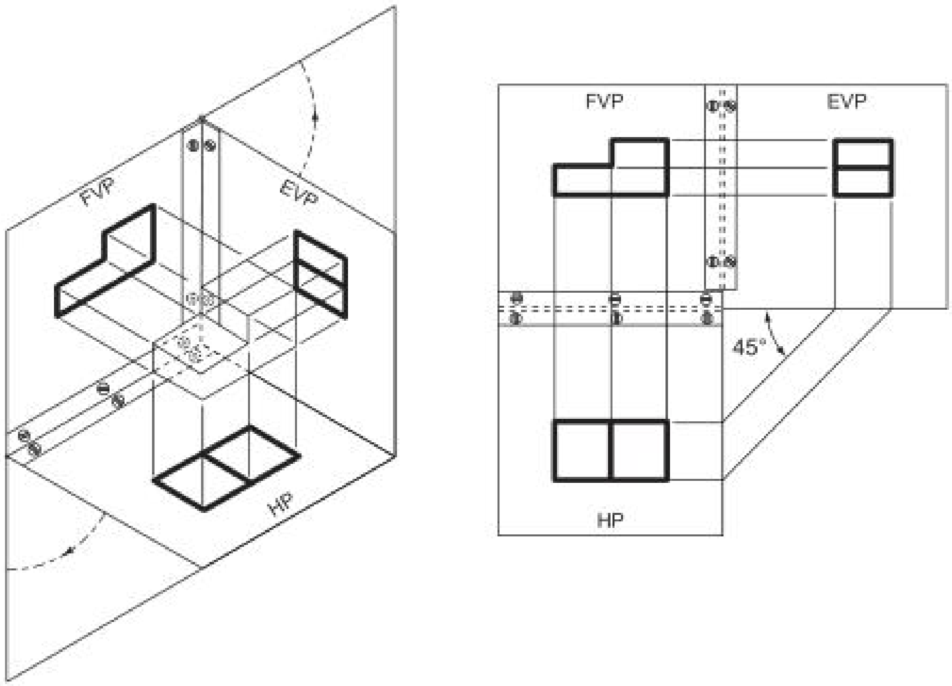


Figure 1.5 – First angle orthographic projection

Figure 1.6 shows the same shaped block drawn in third angle projection. First, draw the view obtained by looking along the arrow marked FE. This gives you the FE. Now look along the arrow marked EE $_1$ (which points from the left) and draw what you see to the left of the FE. This gives you an EE. Now look along the arrow marked EE $_2$ (which points from the right) and draw what you see to the right of the FE. This gives you another EE. Now look down onto the block, along the arrow marked «plan» and draw what you see above the FE. This gives the plan and its exact position is determined by drawing lines from one of the EE at 45°.

Note that with third angle projection, what you see from the left you draw on the left, what you see from the right you draw on the right and what you see from above you draw above.

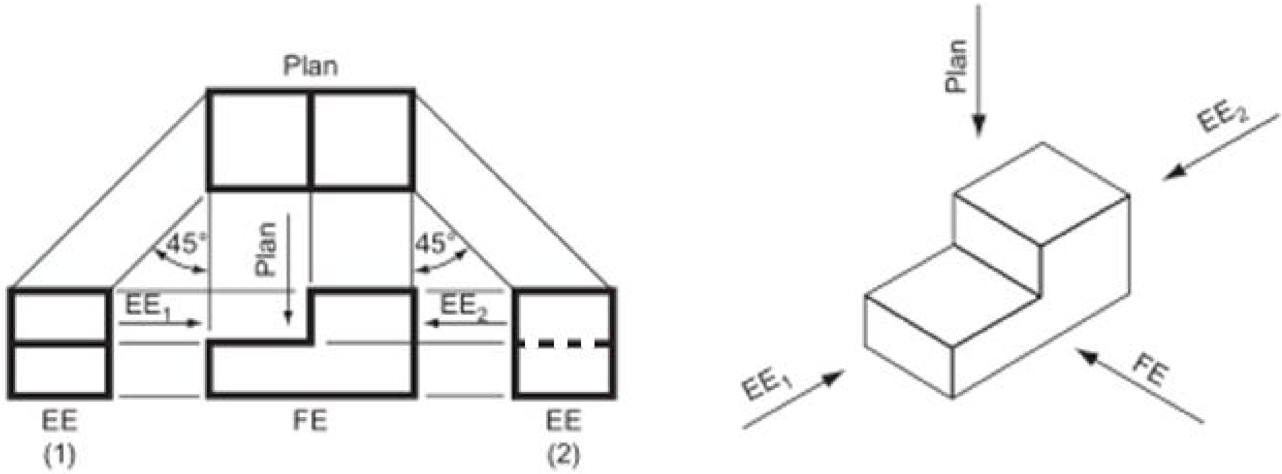


Figure 1.6 – Third angle orthographic projection

Figure 1.7 shows the same block drawn in first angle projection. Again, first draw the view obtained by looking along the arrow marked FE. This gives the FE.

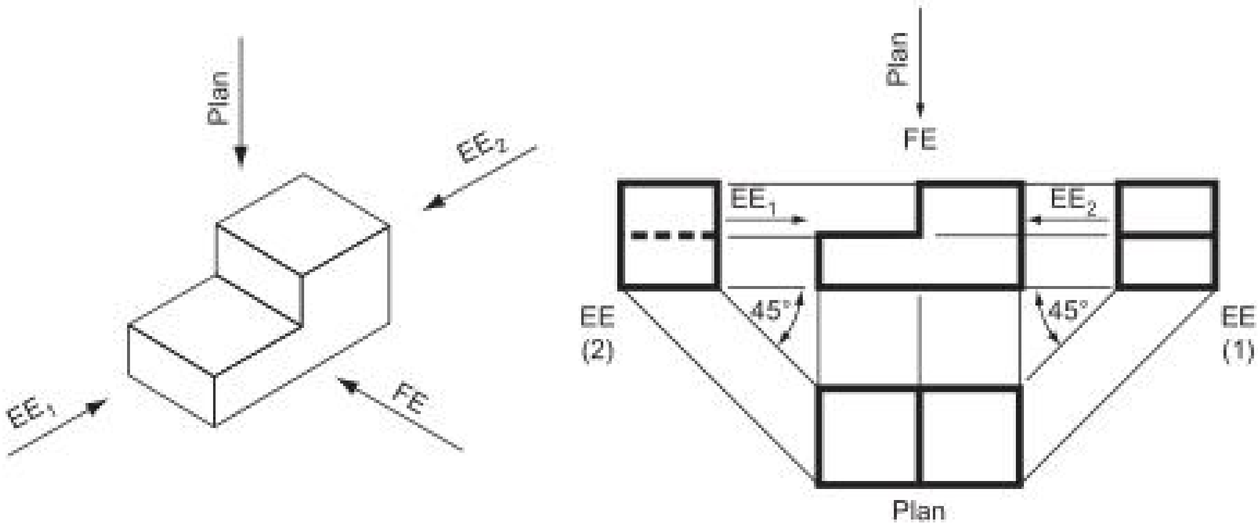


Figure 1.7 – First angle orthographic projection

Now look along the arrow marked EE $_1$ (which points from the left) and draw what you see to the right of the FE. This gives you an EE. Now look along the arrow marked EE $_2$ (which points from the right) and draw what you see to the left of the FE. This gives you another EE. Now look down on the block, along the arrow marked plan and draw what you see below the FE. This gives the plan and its exact position is determined by drawing lines from one of the EE at 45°.

Note that with first angle projection, what you see from the left you draw on the right, what you see from the right you draw on the left and what you see from above you draw below.

1.3 Methods of projection

The methods of descriptive geometry are based on projection, i.e. on a transformation where an image of a three-dimensional object in Euclidean space is projected onto the Euclidean plane. There are two basic types of projection – central and parallel.

Central projection

A plane H and a point S are given in space. The point S is not at infinity and not lying in the plane H ($S \notin H$). The point $T \neq S$ transformations to the point T' is the intersection of the line ST and plane H (Fig. 1. 8).

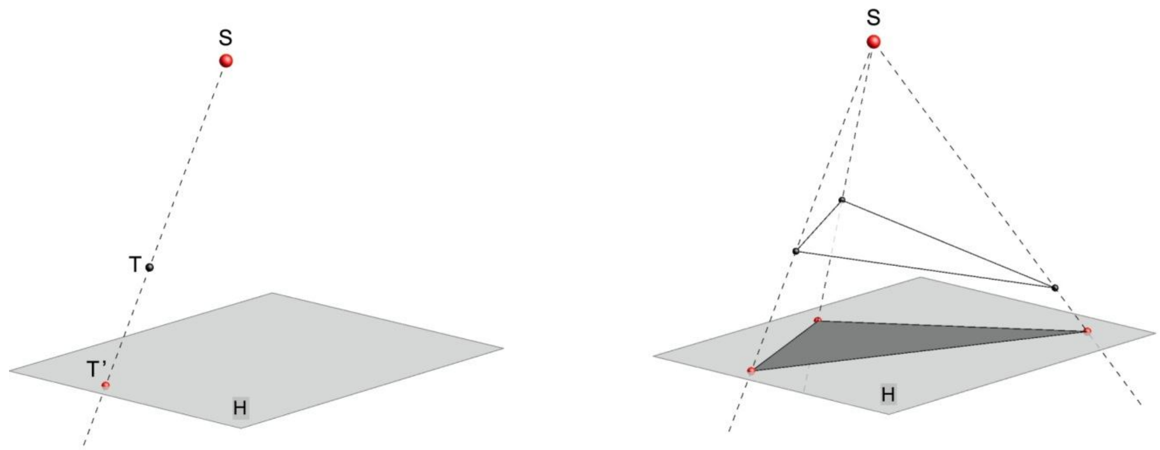


Figure 1.8 – Central projection of the point T and triangle

T' is called the central projection the point T to the plane H from S. The point S is called the center, and the line ST is called ray of the central projection. The plane H is called the projection plane or picture plane.

Parallel projection

A parallel projection is a projection of an object in three-dimensional space oto a fixed plane, known as the projection plane or image plane, where the rays, known as lines of sight or projection lines, are parallel to each other.

If the rays of the projection are orthogonal to the projection plane, then the projection is called an orthogonal projection (Fig. 1.9).

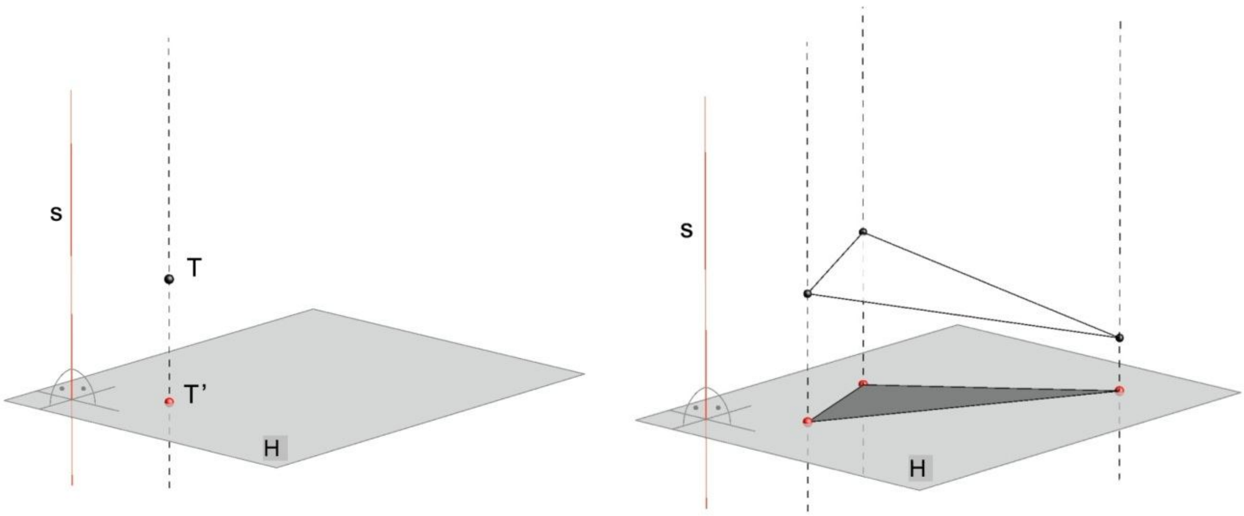


Figure 1.9 – Orthogonal projection of a point T and a triangle

1.4 Projection of a point onto two and three planes of projections

The method of constructing a complex drawing on two mutually perpendicular projection planes was summarized and substantiated by Gaspar Monge.

According to the method, the horizontal plane HP and vertical (frontal) plane FP are mutually perpendicular, and the centers of projection are infinitely distant in a direction perpendicular to the planes of projections. A set of several related projections of figures is called a system of rectangular (orthogonal) projections.

Point A in space is orthogonally projected onto both projection planes:

$$AA_1 \perp HP;\ AA_1 \cap HP = A_1;$$

$$AA_2 \perp FP;\ AA_2 \cap FP = A_2.$$

The projecting rays AA_1 and A_2 are mutually perpendicular and create in space a projecting plane A_1 A_X A_2, perpendicular to both planes of projections. This plane intersects the projection planes along the lines crossing through the projections of point A (Fig. 1.10).

To obtain 2D drawing view, we combine the horizontal plane of projections HP with the front plane FP rotation about the axis X (FP / HP) and rotation profile plane PP about the axis Z (FP / PP) (Fig. 1.10). Then both projections of the point A are found on the line perpendicular to the axis X (FP / HP) and a horizontal line perpendicular to the axis Z (FP / PP). The straight line connecting the horizontal A_1 and the frontal A_2 projections of the point is called the vertical projection line. The straight line connecting the frontal A_2 and profile A_3 projections of the point is called the horizontal projection line.

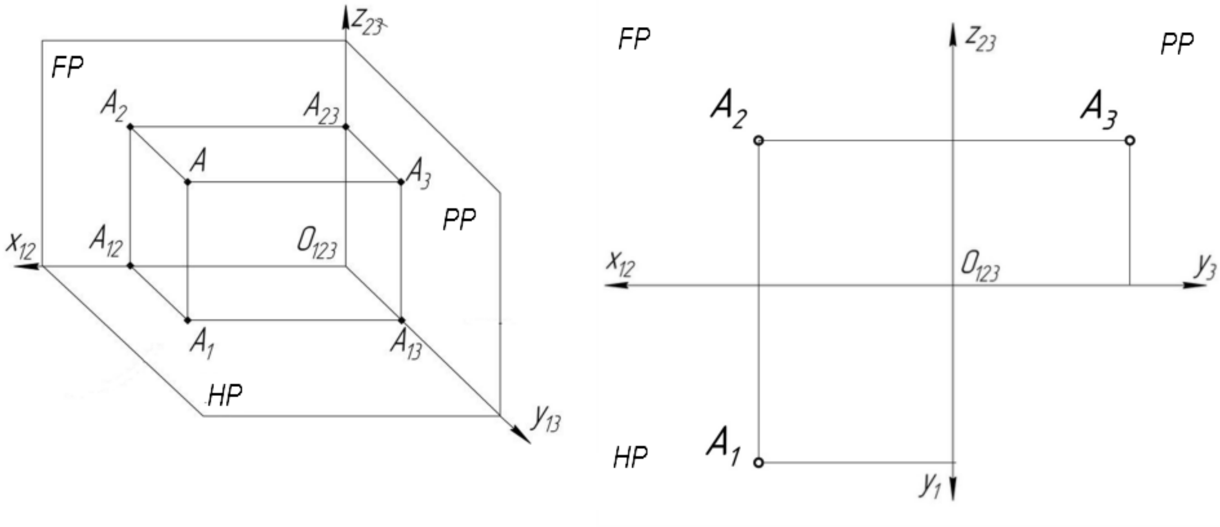


Figure 1.10 – Orthogonal projection and complex drawing of a point

1.5 Projection of straight line

A line is a geometric primitive that has length and direction, but no thickness.

Straight line is the locus of a point, which moves linearly. Straight line is also the shortest distance between any two given points.

The location of a line in projection quadrants is described by specifying the distances of its end points from the FP (VP), HP and PP.

A line in space can be arranged as follows:

– inclined to all the planes (Fig. 1.11);
– parallel to one plane and inclined to the others (Fig. 1.12-1.14);
– parallel to both planes and perpendicular to the third one (Fig. 1.15-1.17).

The projection of a line can be obtained by projecting its end points on planes of projections and then connecting the points of projections. The projected length and inclination of a line can be different compared to its true length and inclination.

The projection of a line that is not parallel to any of the principal planes is shown in Figure 1.11.

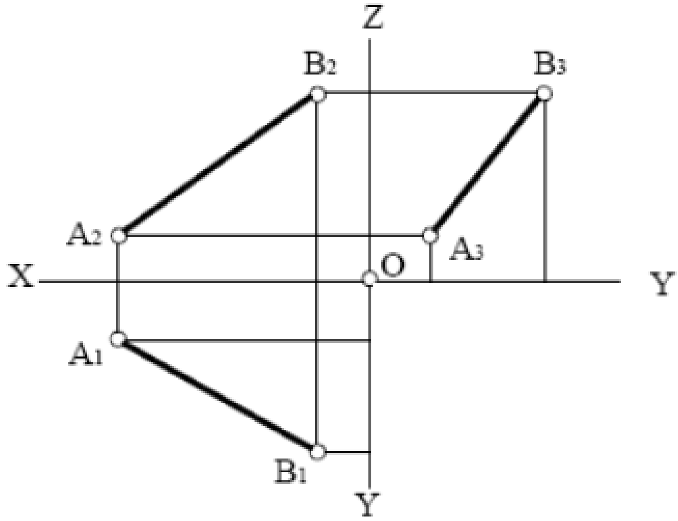


Figure 1.11 – Orthographic projection of a straight line in general position

Figure 1.11 shows a straight line AB suspended between the three principal planes. Projectors from A and B, perpendicular to the planes, give the projection of AB on each of the principal planes.

A straight line that is not parallel and is not perpendicular to any of the projection planes is called a straight line. Example of a line is shown in Figure 1.11. The segment [AB] straight to none of the projection planes does not appear in true size $[A_1B_1]<[AB]$, $[A_2B_2]<[AB]$, $[A_3B_3]<[AB]$.

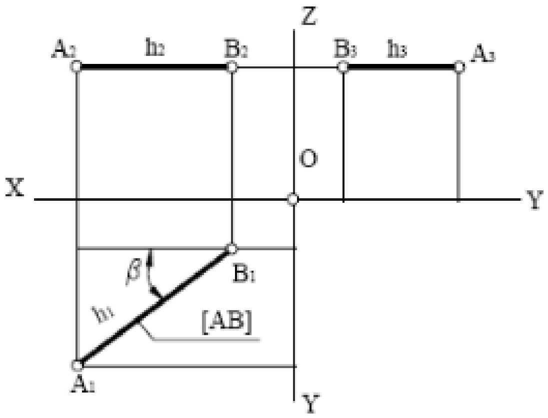
The general position has different angles of inclination to the projection planes. The angle of inclination of a straight line to the plane of projections means the angle formed between the line itself and its corresponding projection.

When a line is parallel to a plane, the projection of the line onto that plane will be its true length. There are three position of parallel line relative to the projection planes.

A line parallel to the horizontal plane of the projections is called the *level line* and is indicated in the drawings by *h* (Fig. 1.12).

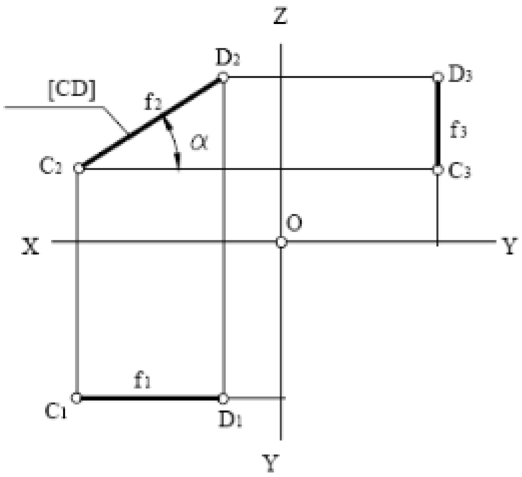
A line parallel to the frontal plane of the projections is called the *frontal line* and is indicated in the drawings by *f* (Fig. 1.13).

A line parallel to the profile plane of the projections is called the *profile line* and is indicated in the drawings by *p* (Fig. 1.14).



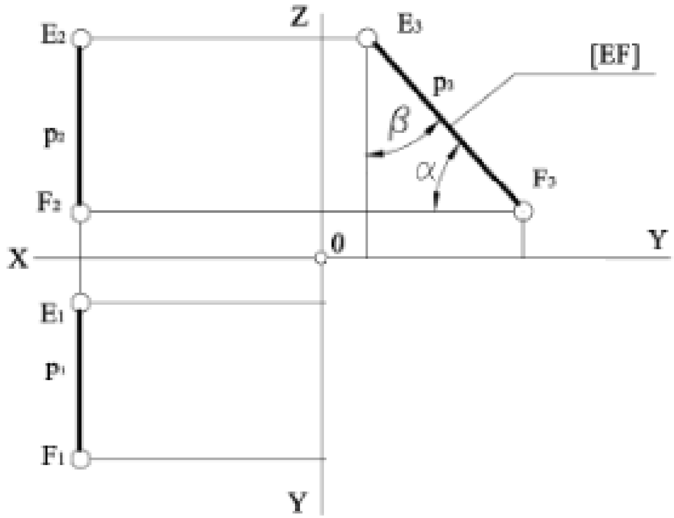
$h \parallel HP$
$h_2 \parallel OX$
$h_3 \parallel O$У
$A_1B_1 = [AB]$
$\beta = OX \wedge A_1B_1 = AB \wedge FP$

Figure 1.12 – Orthographic projection of a level line h



$f \parallel FP$
$f_1 \parallel OX$
$f_3 \parallel OZ$
$C_2D_2 = [CD]$
$\alpha = OX \wedge C_2D_2 = CD \wedge HP$

Figure 1.13 – Orthographic projection of a frontal line f

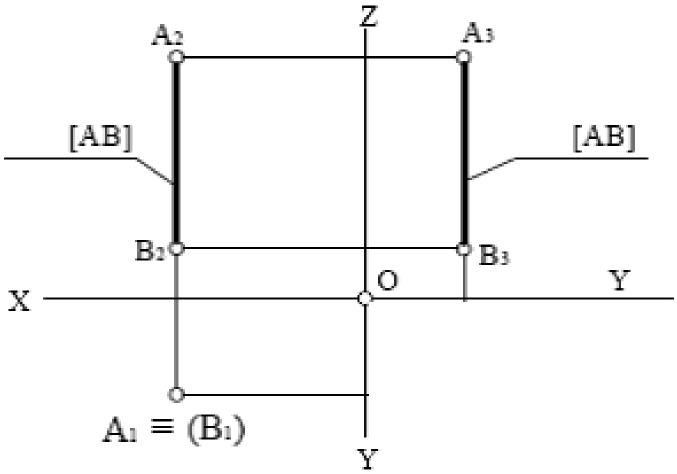


p || PP
$p_2 \perp OX$
$p_1 \perp OX$
$E_3F_3 = [EF]$
$\alpha = OY \wedge P_3 = EF \wedge HP$
$\beta = OZ \wedge P_3 = EF \wedge FP$

Figure 1.14 – Orthographic projection of a profile line p

Straight segments perpendicular to one of the projection planes are called projection lines, and they are simultaneously parallel to the other two projection planes. In projection lines one projection is projected to a point and two other projections are parallel to the most direct and coincide with the direction of the line of communication.

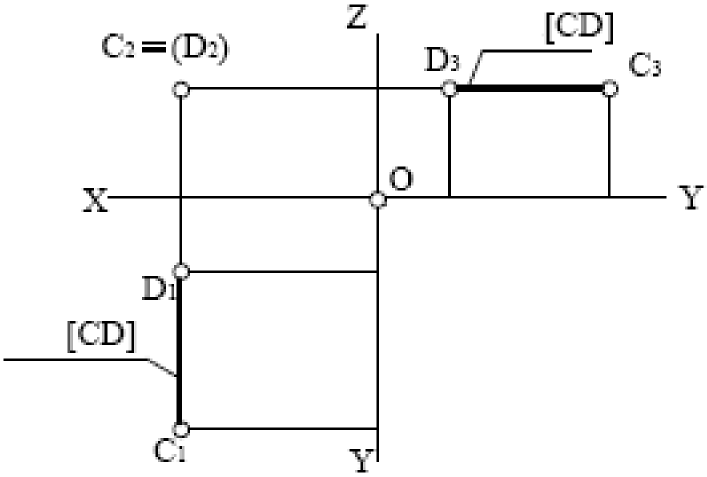
The straight segment perpendicular to the horizontal plane of projection HP and simultaneously parallel to the frontal FP and profile PP projection planes called the horizontal projection line (vertical line) (Fig. 1.15).



$AB \perp HP$
AB || FP, AB || PP
$A_2B_2 \parallel OZ$
$A_3B_3 \parallel OZ$
$A_1 \equiv (B_1)$ – point

Figure 1.15 – Orthographic projection of a vertical line

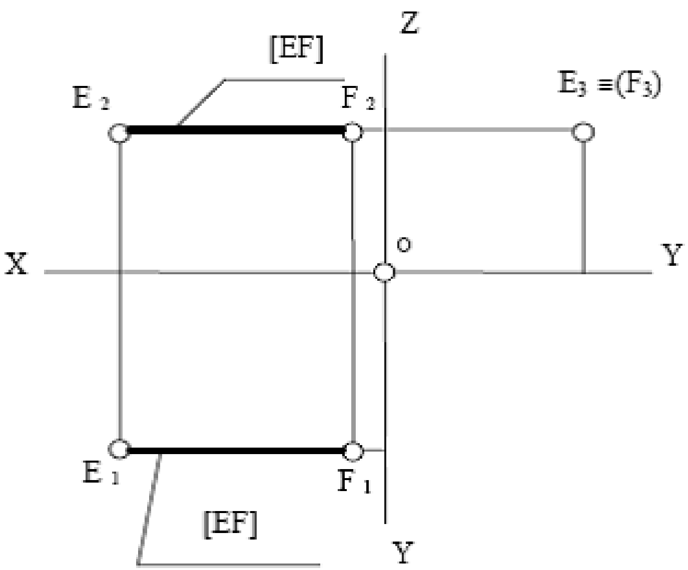
The straight line perpendicular to the frontal plane of projections FP and at the same time parallel to the horizontal HP and profile PP projection planes is called the frontal projection line (Fig. 1.16).



CD ⊥ FP
CD || HP
CD || PP
C_1D_1 || OY
C_3D_3 || OY
$C_2 \equiv (D_2)$ – point

Figure 1.16 – Orthographic projection of a frontal projection line

The straight segment perpendicular to the profile plane of projections P3 and simultaneously parallel to the horizontal HP and frontal FP planes of projections, is called the profile projection line (Fig. 1.17).



EF ⊥ PP
EF || HP
EF || FP
E_1F_1 || OX
E_2F_2 || OX
$E_3 \equiv (F_3)$ – point

Figure 1.17 – Orthographic projection of a profile projection line

1.6 The rule of a right triangle

For a straight forward position, there is a need to determine the natural size of the segment and the angles of inclination to the projection planes. Consider Figure 1.18, which follows the rule of a right triangle.

Consider the segment AB and construct its orthogonal projection on the horizontal and frontal planes of projections. We get two right triangles ΔAB_0B and ΔAA_0B. The hypotenuse [AB] is a natural value, $\alpha = \angle BAB_0$ is the angle of inclination of the line to the horizontal plane of projections HP, $\beta = \angle ABA$ is the angle of inclination of the line to the front plane of the projections FP. For triangle ΔAB_0B the catheter AB_0 is equal to the horizontal projection A_1B_1 of the segment [AB], the second catheter BB_0 is equal to the difference of distances from the ends of the segment (points A and B) to the horizontal plane of projections is ΔZ.

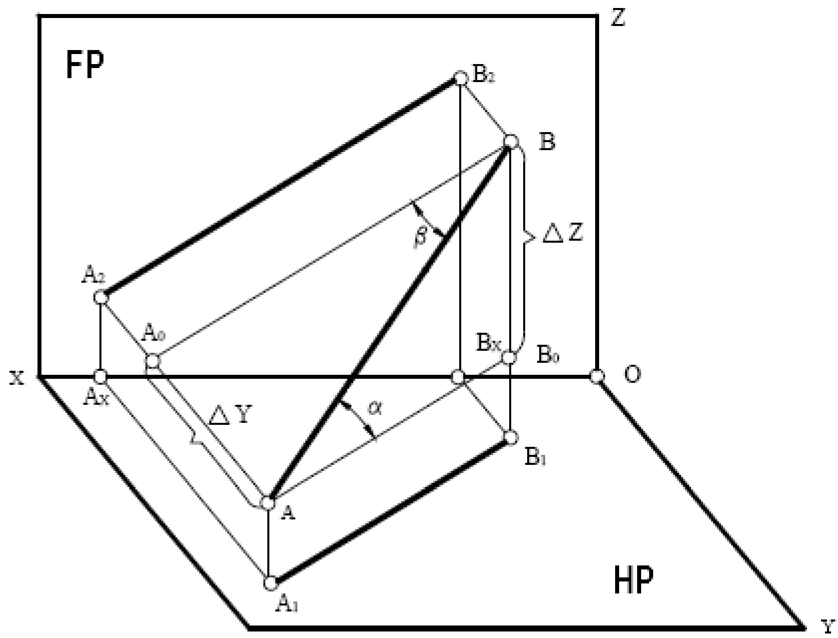


Figure 1.18 – A straight line of general position in space

Similar conclusions also follow from the consideration of the triangle ΔAA_0B.

To determine the true length of the line segment and the angle of inclination of the line to a certain projection plane it is necessary to construct on the orthographic drawing (Fig. 1.19). A right triangle on the plane of projections relative to which the angle of inclination of the line is determined like a segment projection on the same projection plane. The second catheter is the difference of the distances from the ends of the segment to the same projection plane. The angle between the corresponding projection of that segment and the hypotenuse is equal to the angle of inclination of the line directly to this plane of projections.

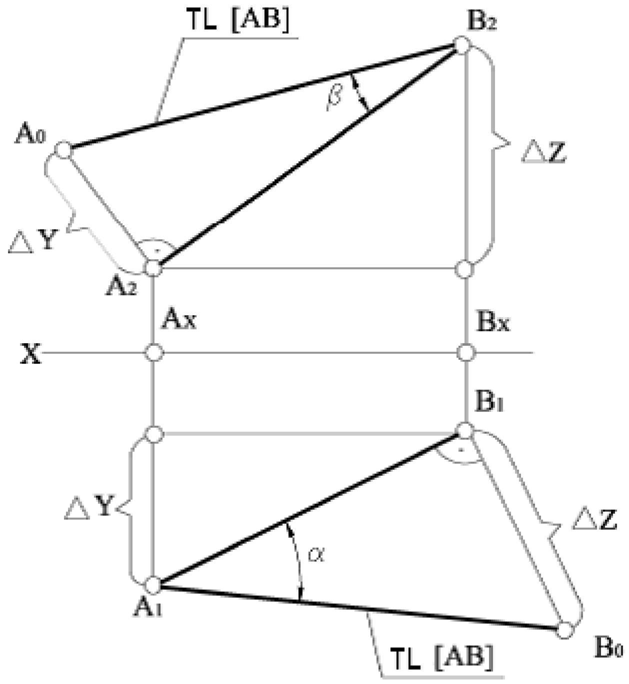


Figure 1.19 – The true length of the line segment and the angle of inclination of the line to the projection planes

1.7 The relative position of the lines in the drawing

Two lines in space can coincide, be parallel, intersecting, non-intersecting.

If two lines intersect at some point K, the projections of this point must belong to the same projections of the lines. The points of intersection of the same projections of the intersecting lines must lie on the same projection line (Fig. 1.20).

Two lines are parallel if in the orthographic drawing their eponymous projections are parallel (Fig. 1.21) or coincide on one of the projection planes (Fig. 1.22).

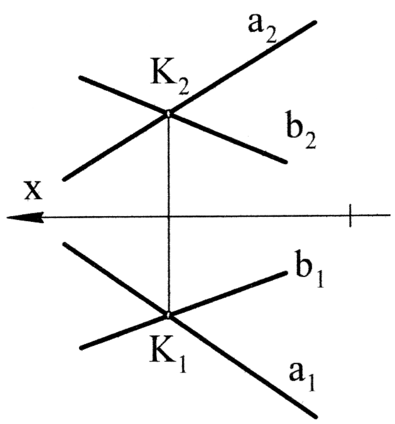


Figure 1.20 –
Intersecting lines (a ∩ b)

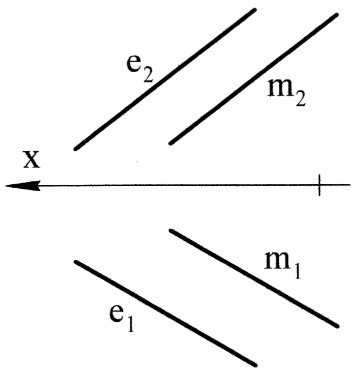


Figure 1.21 –
Parallel lines (e || m)

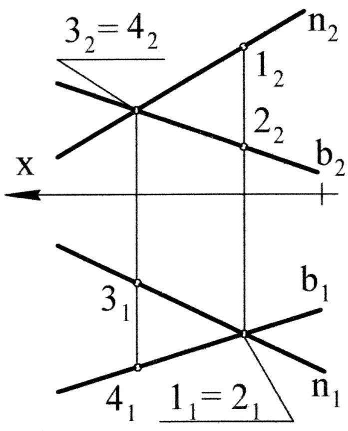


Figure 1.22 –
Non-intersecting lines
(b ∸ n)

The points of intersection of eponymous projections of passing lines correspond in space to two points: in one case, these are points 1 and 2, and in the other case, points 3 and 4 are located on the lines. The point of intersection of the horizontal projections of the lines correspond to the two frontal projections of points 1 and 2. The applique (height) of point 1 is greater, therefore, the line l at this point passes above the line m and will be visible when viewed from above (Fig. 1.22). The other two points 3 and 4, which coincide in the frontal projection, have different ordinates. The ordinance of point 4 is larger than ordinance of point 3. Therefore, the line l in this place is closer to the viewer and will be visible when viewed from the front (Fig. 1.22).

The lines are lying on the incidental straight are the projections coincidentally called competing ones. From two competing points visible point has the higher corresponding coordinate. Consideration of the competing contour points of the relative position of the points makes it possible to determine the visibility of the non-intersecting lines if they are, for example, edges of a polyhedron. The visibility of an element of the object is determined separately for each projection.

1.8 Projecting of a right angle

A right angle is projected at a true length if one of its sides is parallel to the projection plane and the other side is not perpendicular to that plane. In Figure 1.23, a, the straight line BC is level line, the right angle is projected to the true length on the horizontal plane of projections. In Figure 1.23, b is the straight line BC is frontal line, the true size of the angle is seen on the front plane.

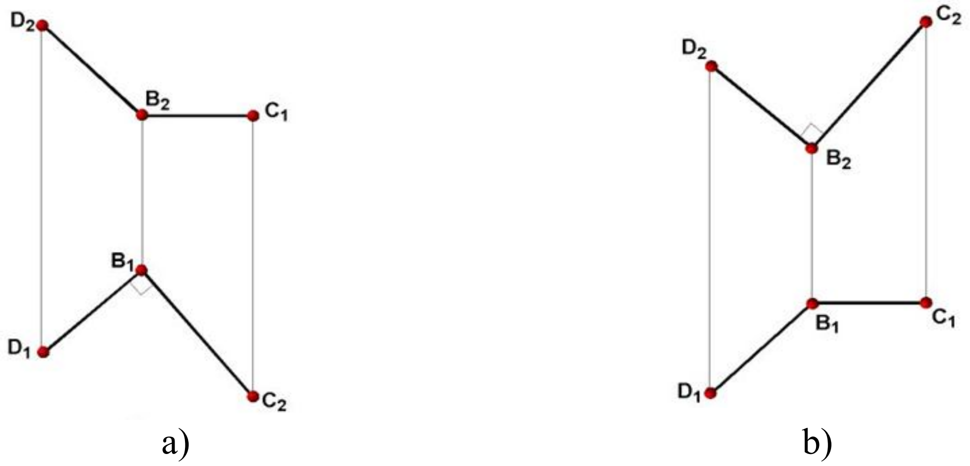


Figure 1.23 – Projecting of a right angle

The right-angle projection rule is used when solving problems to find the distance from a point to a straight special position. Figure 1.24 shows an example of finding the distance from point C to the horizontal straight line h.

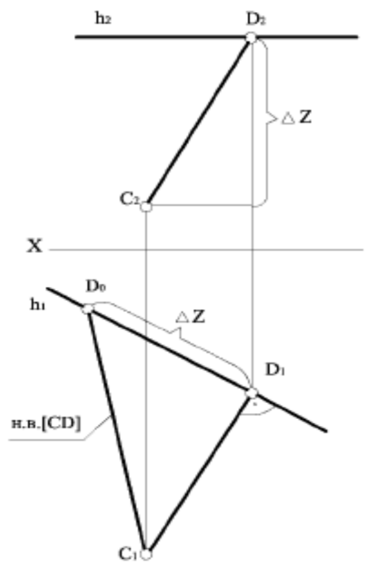


Figure 1.24 – Finding the distance from point C to the horizontal straight line h

1.9 Point on a straight line. Traces of a straight line

A point lies on a straight line when the projections of this point lie on the same projections of this line and on a common line of projection (point C in Fig. 1.25).

A point does not belong to a straight line if none of the projections of the point belongs to the corresponding projection of the straight line or only one of the projections of the point belongs to the same projection of the straight line (point D in Fig. 1.25).

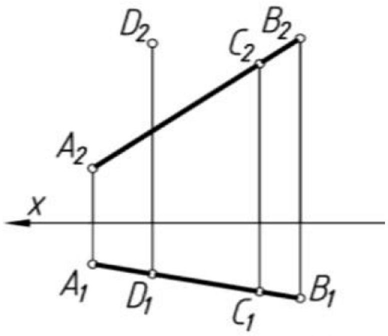


Figure 1.25 – Points and line

The point of intersection of the line with the plane of projections is called the trace of the line. The point M (M_1, M_2, M_3) of intersection of straight line with the horizontal plane of projections HP has the name of the horizontal trace. The point N (N_1, N_2, N_3) of the intersection of straight l with the frontal plane of projections FP has the name of the frontal trace; the point P (P_1, P_2, P_3) of the intersection of straight line with the profile plane of projections PP is called the profile trace (Fig. 1.26).

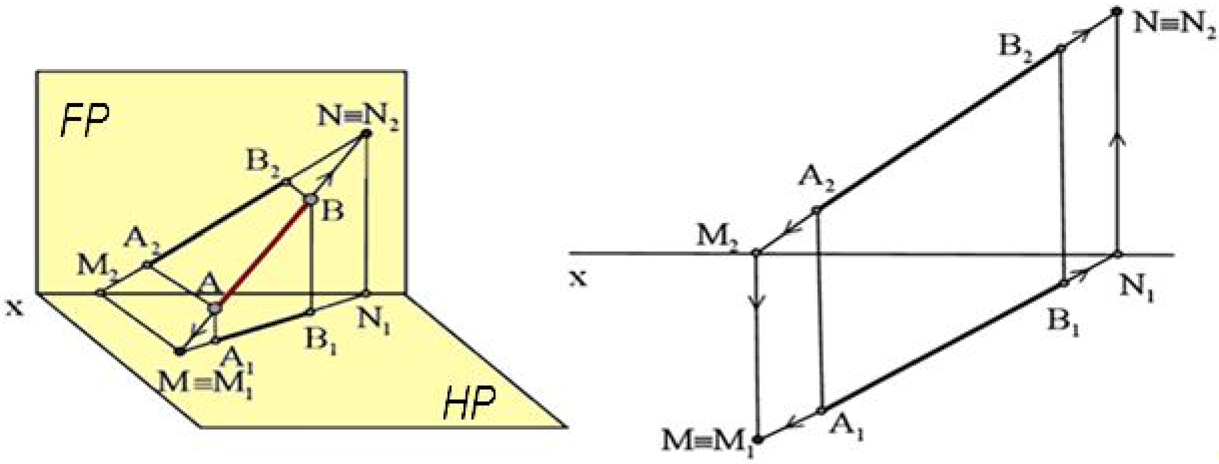
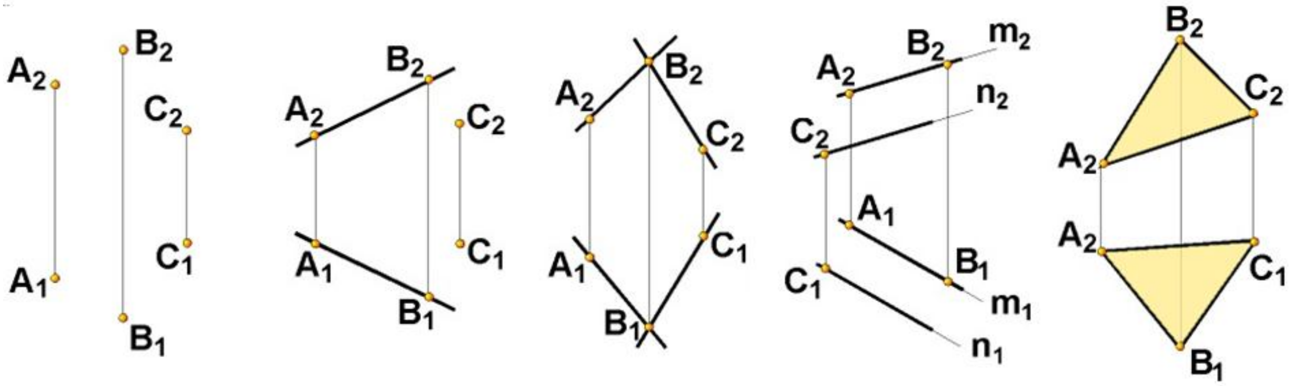


Figure 1.26 – The traces M and N of a straight line

1.10 Projection of a plane

The position of a plane in space can be determined by three points that do not lie on one straight line (Fig. 1.27, a); a straight line and a point outside it (Fig. 1.27, b); two straight intersecting lines (Fig. 1.27, c) or two parallel straight lines (Fig. 1.27, d); any flat figure (Fig. 1.27, e).



a) b) c) d) e)

Figure 1.27 – Methods of defining a plane in space

Planes are often to be infinite in size. The definition of a plane simply sets its orientation in 3D space. Plane positions:

– inclined to all three principal planes;

– perpendicular to one of the principal planes of projection;

– parallel to one of the principal planes of projections.

Plane of inclined to all three principal planes is flat figure nightie perpendicular non parallel to HP, FP and PP projections planes (Fig. 1.28).

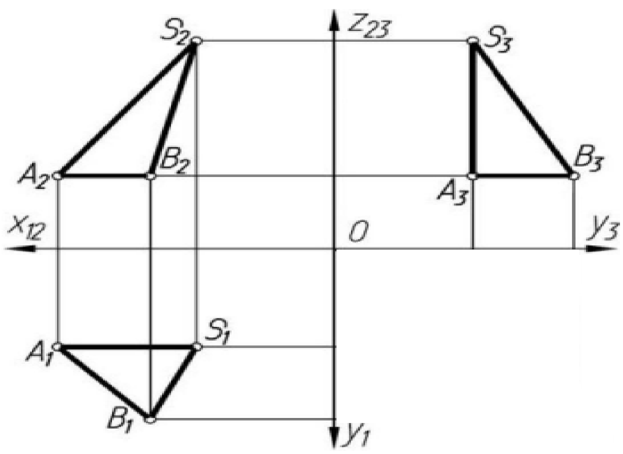


Figure 1.28 – A plane inclined to all three principal planes

Planes perpendicular to one of projection planes (HP, FP or PP)

The vertical plane or horizontal progecting plane is perpendicular to the horizontal plane of the projections (Fig. 1.29). The horizontal projection of the plane is a straight line that coincides with the horizontal trace of the plane. Horizontal projections of points and figures lying in this plane coincide with its horizontal trace.

The frontal projecting plane is perpendicular to the frontal plane of the projections. The frontal projection of the triangle ABC belonging to the plane coincides with the frontal trace. The angle α between the planes Δ and HP is projected without distortion (Fig. 1.30)

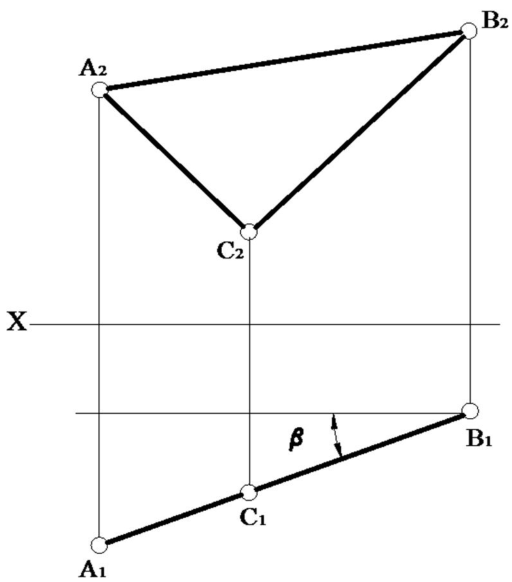


Figure 1.29 – A horizontal progecting plane

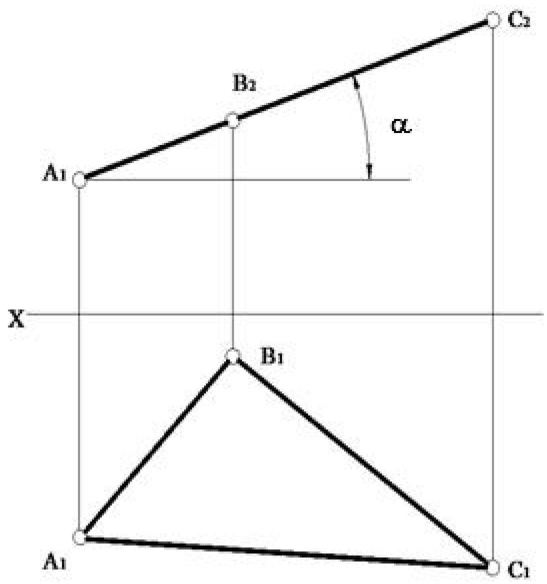


Figure 1.30 – A frontal projecting plane

The profile projecting plane is perpendicular to the profile plane of the projections (Fig. 1.31). To see the projecting trace of a plane, it is necessary to construct a profile projection, since the horizontal and front projections of such a plane do not differ from the projections of the plane of the general position.

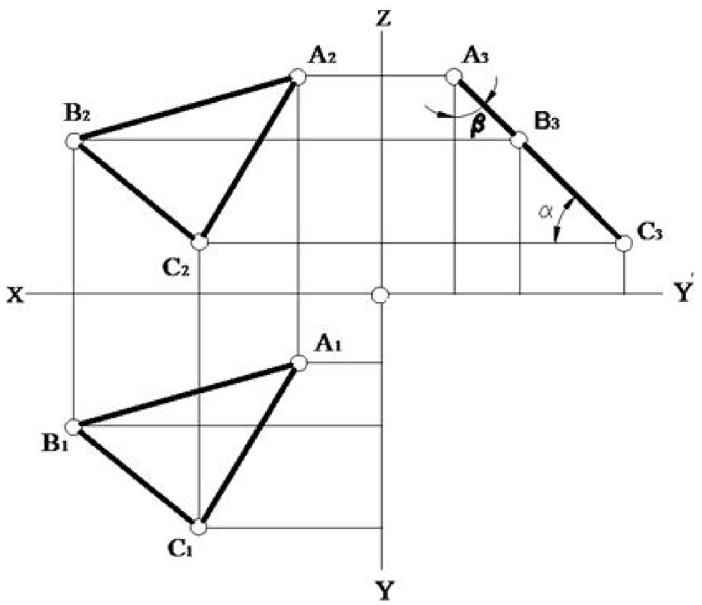


Figure 1.31 – A profile projecting plane

Planes parallel to one of projection planes (HP, FP or PP)

The horizontal level plane is parallel to the horizontal plane of projections (Fig. 1.32). Its horizontal projection is a true size.

The frontal level plane is parallel to the vertical plane of projections (Fig. 1.33). Its frontal projection is a true size.

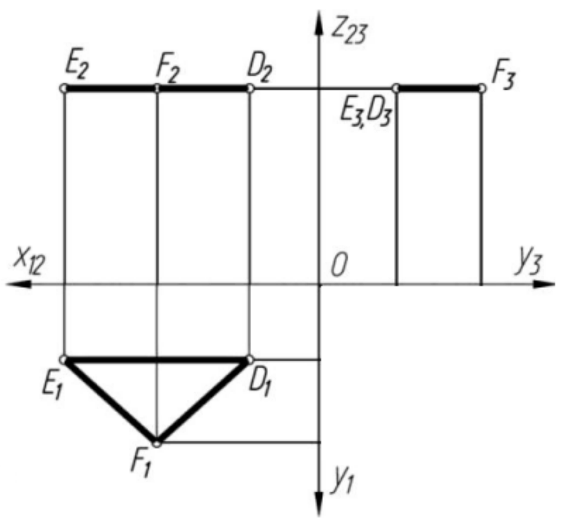


Figure 1.32 – A horizontal level plane

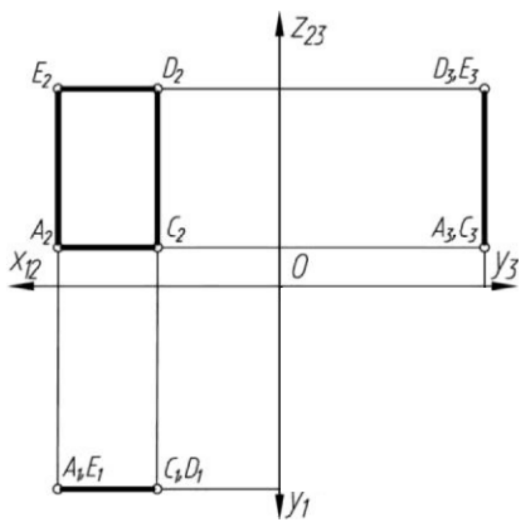


Figure 1.33 – A frontal level plane

The profile level plane is parallel to the vertical plane of projections (Fig. 1.34). Its profile projection is a true size.

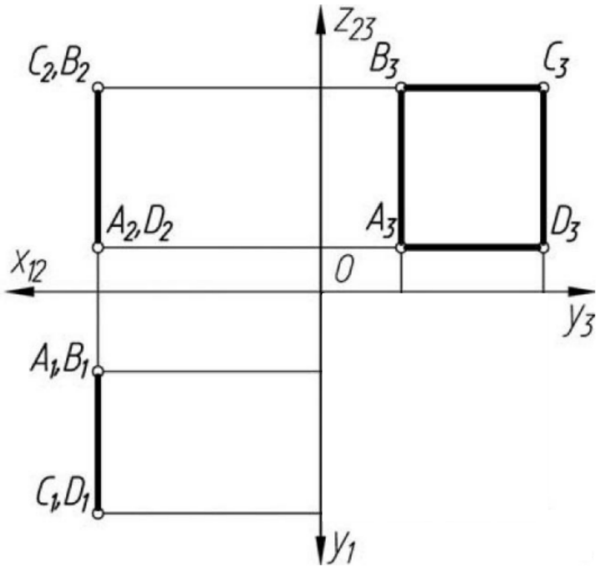


Figure 1.34 – A profile level plane

The plane level lines

The plane level lines are called lines belonging to a given plane and parallel to one of the projection planes: horizontal h, front f and profile p straight lines (Fig. 1.35)

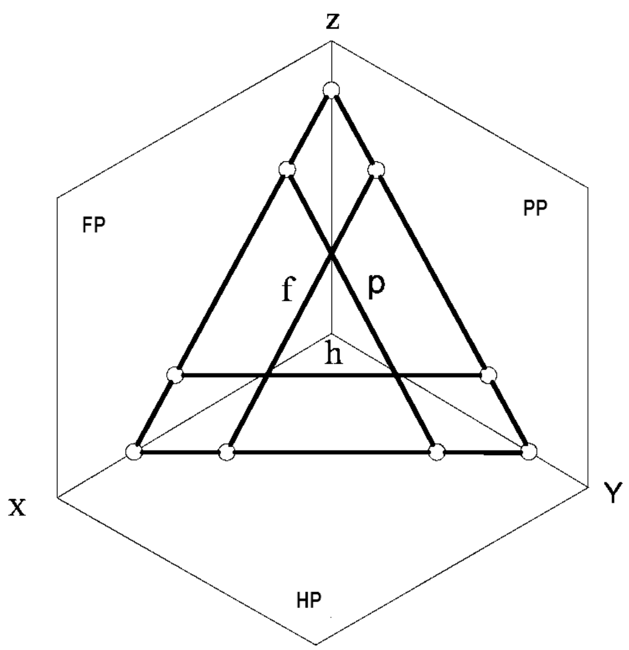


Figure 1.35 – The plane level lines

Horizontal level line is the line belongs to the plane and parallel to the horizontal plane of the projections HP (Fig. 1.36).

Frontal level line is the line belongs to the plane and parallel to the frontal plane of the projections FP (Fig. 1.37).

Profile level line is the line belongs to the plane and parallel to the profile plane of the projections PP (Fig. 1.38).

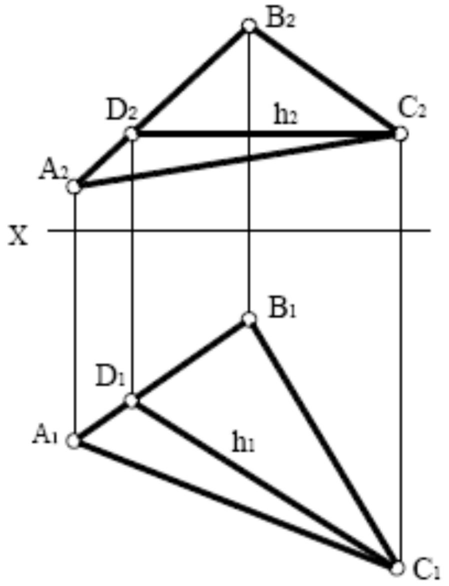


Figure 1.36 – A horizontal level line h of a plane

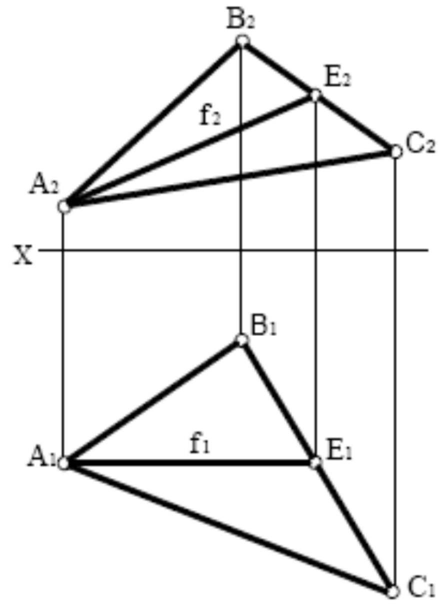


Figure 1.37 – A frontal level line f of a plane

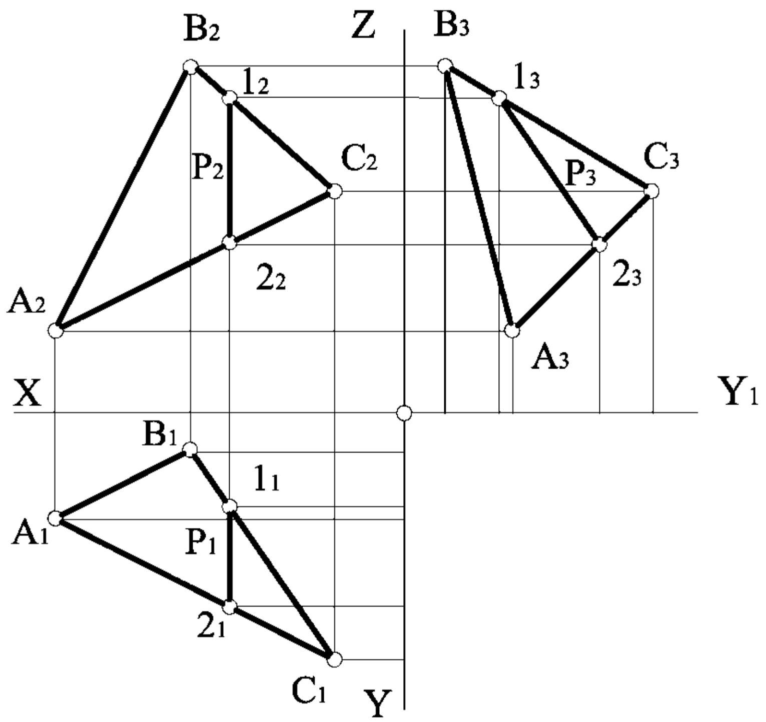


Figure 1.38 – A profile level line p of a plane

LECTURE 2 METRICAL AND POSITIONAL PROBLEMS

2.1 Parallelism of planes

If two intersecting straight lines of the same plane are parallel to two intersecting straight lines of the second plane, then the planes are parallel.

Figure 2.1 shows an example of a plane Σ ($l \cap m$) that is parallel to the given θ ($a \cap b$) through point A.

Figure 2.2 shows an example of a plane Σ ($l \cap m$) that is parallel to a given θ ($a \parallel b$) through point A. To construct a plane θ given by parallel lines, we draw an additional line n that lies to this plane because it crosses through two points of this plane.

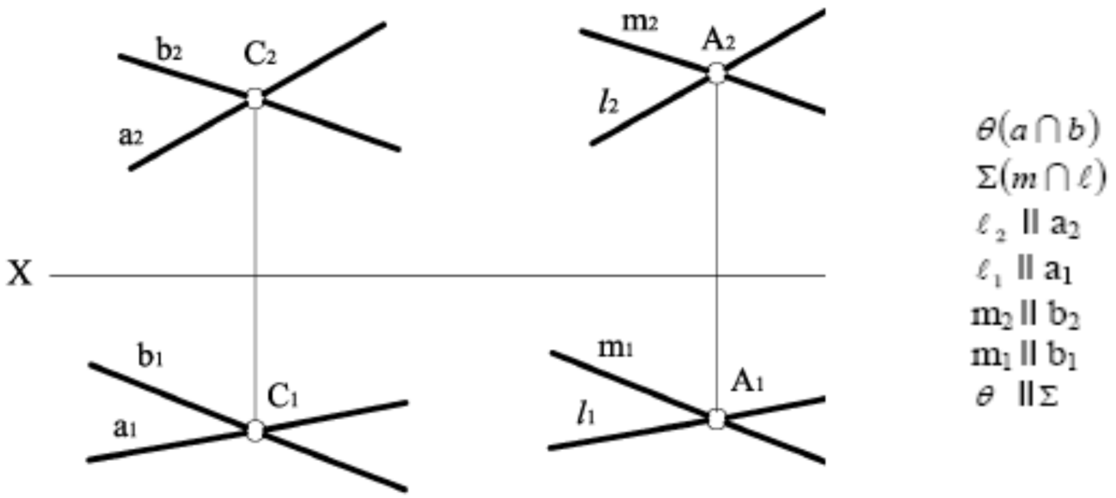


Figure 2.1 – Parallel plane Σ(l ∩ *m*), in point A

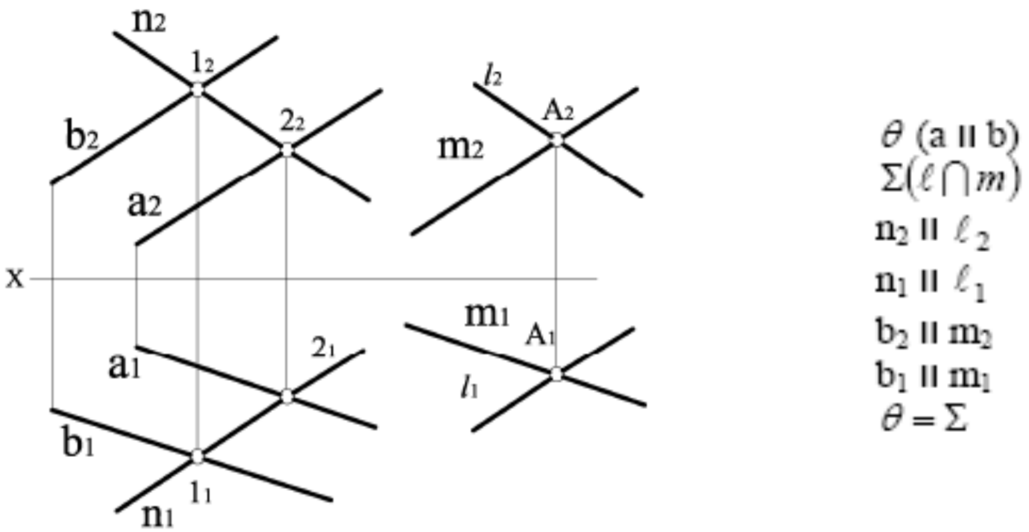


Figure 2.2 – Parallel plane Σ(l ∩ *m*), in point A

2.2 Intersection of planes

If two planes intersect in a straight line, any two points common to these planes or one point and direction of the intersection line form the intersection line of these planes.

Figure 2.3 shows an example of a line of the intersection of two planes of general position.

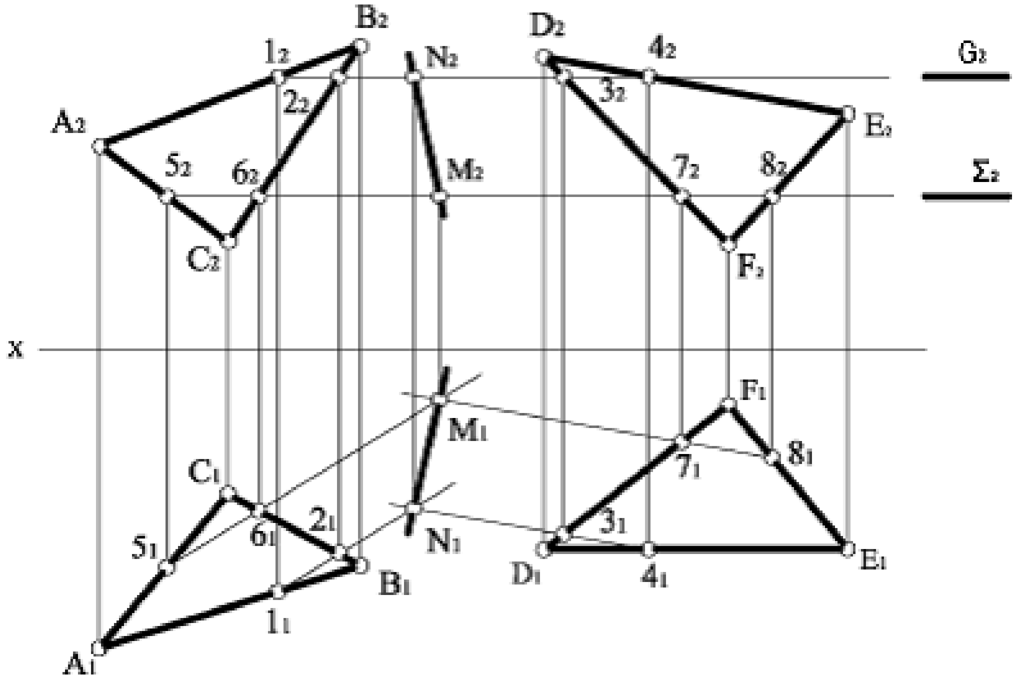


Figure 2.3 – Construction of the intersection line of two planes

Problem of the definition of the intersection line of plane θ (ABC) with plane Λ (DEF) is performed in the following sequence:

The algorithm for solving the problem:

1. Draw an auxiliary horizontal plane of level G, which intersects both planes, $G_2 \parallel OX$.

2. Determine of the frontal projections of the intersection lines of both planes due to the properties of the level plane: $\theta_2\ (A_2\ B_2\ C_2) \cap G_2 = 1_2 – 2_2$, $\Lambda_2\,(D_2\ E_2\ F_2) \cap G_2 = 3_2 – 4_2$.

3. Using the projection relation and the law of belonging, we determine the horizontal projections of the intersection lines of both planes, as well as a common point belonging to three planes simultaneously: $(1_1 – 2_1) \cap (3_1 – 4_1) = N_1$.

4. Using the projection line and the law of belonging, we determine the frontal projection of the common point N_2 belonging to the trace G_2.

To determine the line of intersection of the planes θ and Λ, we need another common point M, which is found using another auxiliary plane Σ in the same sequence: θ (ABC) ∩ Λ(DEF) = MN.

2.3 Parallel line and plane

A straight line is parallel to the plane if there is a straight line in that plane that is parallel to the given straight line.

Through the point not lying in the plane, you can draw an infinite number of lines that are parallel to the given plane. To obtain one variant of construction additional conditions are necessary, for example, to construct a line parallel to two planes simultaneously.

Figure 2.4 shows an example of construction in a complex drawing through the point D of a line l, which is parallel to the given plane θ (ABC) and the horizontal plane of the projections HP.

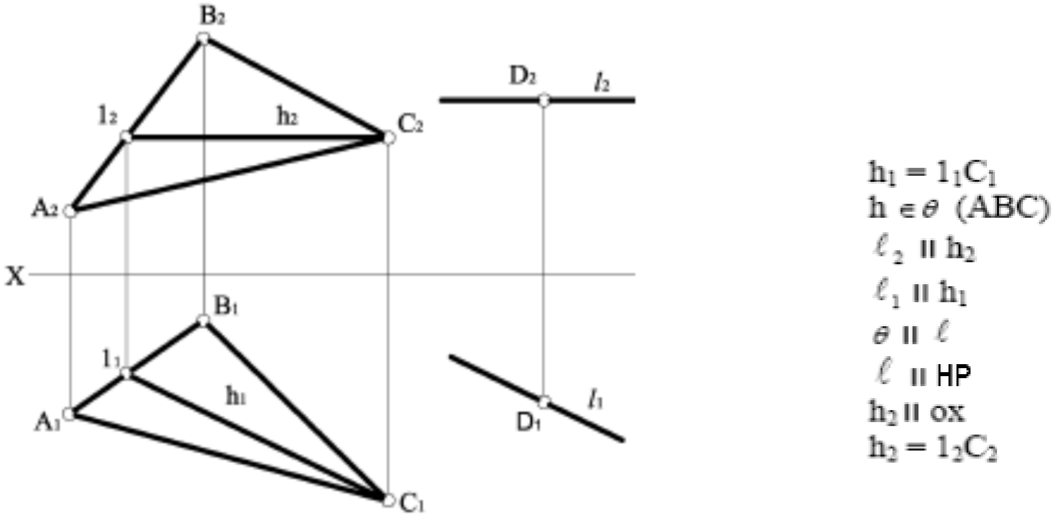


Figure 2.4 – Construction of a straight line l parallel to the plane θ(ABC)

2.4 Intersection of straight and plane

The problem of finding the point of intersection of a line with a plane belongs to positional problems. These tasks are to determine the relative position of geometric shapes and the intersection of geometric shapes.

Figure 2.5 shows a visual representation of competing points according to HP and FP. Points belonging to different geometric shapes and lying on the same projecting line are called competing according to the projection plane which the projecting line is perpendicular.

Points A and B are in competition according to the horizontal plane of projections HP, and points C and D with respect to the frontal plane of projections FP. Figure 2.6 shows an example image of competing points in a complex drawing.

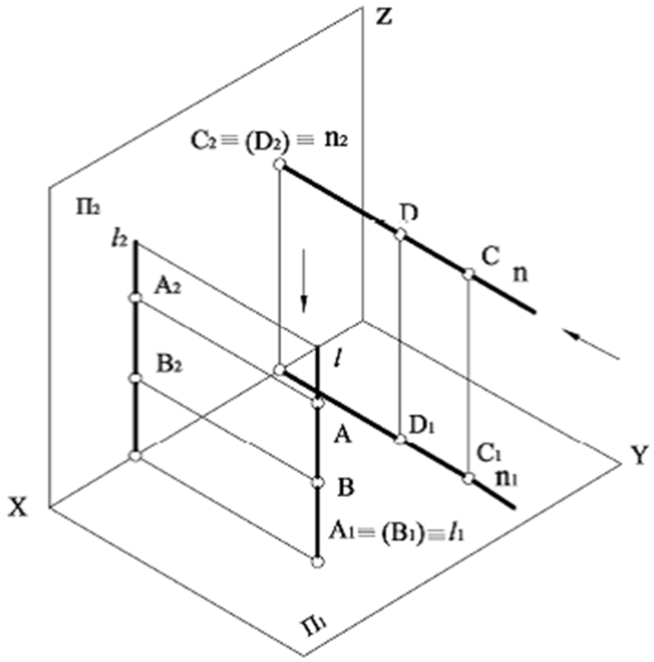


Figure 2.5 – Model of competing points

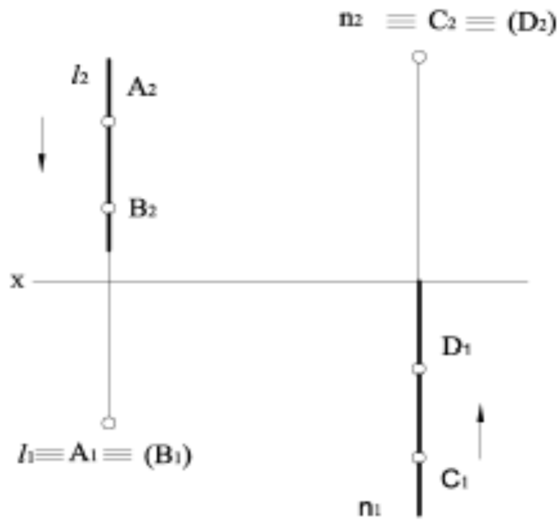
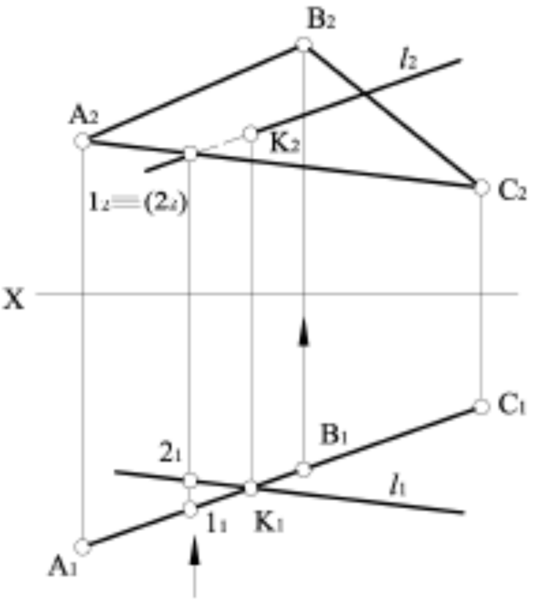


Figure 2.6 – Drawing of competing points

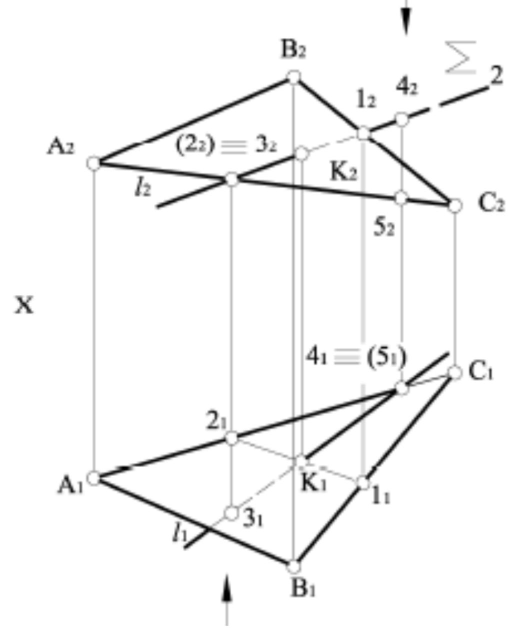
In the complex drawing of the two competing points will be visible the projection, which is located at a longer distance from the plane of projections, relative to which they are competing.

The problem of intersection of a line with a plane is one of the main positional problems. Figure 2.7 shows an example of the construction of a point of intersection of a straight general position l with a horizontally projecting plane θ (ABC) in the complex drawing. Figure 2.8 shows in the complex drawing an example of constructing a point of intersection of a straight general position l with a plane of general position θ (ABC).



$$\theta(ABC) \perp HP$$
$$(A_1B_1C_1) \cap \ell_1 = K_1$$

Figure 2.7 – Intersection of straight line l with horizontal projection plane θ(ABC)



$$\ell_2 \equiv \Sigma_2$$
$$\Sigma_2 \cap \theta_2 = 1_2 - 2_2$$
$$(1_1 - 2_1) \cap \ell_1 = K_1$$

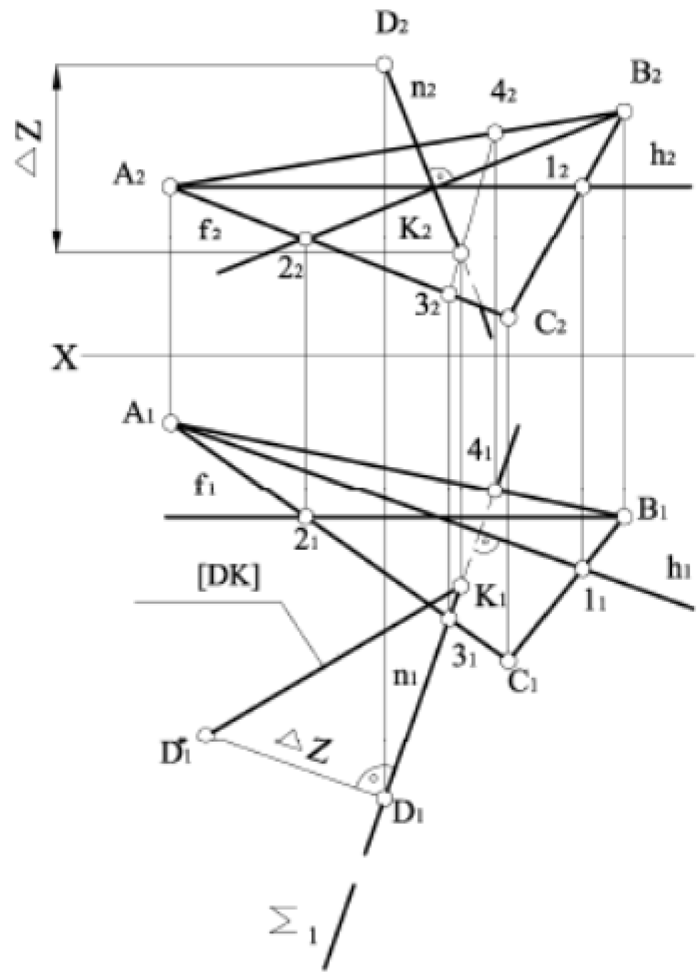
Figure 2.8 – Intersection of straight l with plane of general position θ(ABC)

2.5 Perpendicularity of straight line and plane

A straight line is perpendicular to the plane if it is perpendicular to each of the two intersecting lines lying in that plane.

If you take the horizontal and front lines of the plane in the plane, then you can use the right angle projection theorem.

Figure 2.9 shows an example of determining the distance from point D to the plane of general position of the ABC. To do this, it is necessary to draw a perpendicular from the point D to the plane of the ABC, determine its basis and find the life size of the segment of that perpendicular.



$h_2 \parallel ox$

$h_2 = 1_2 A_2$

$h_1 = 1_1 A_1$

$n_1 \perp h_1$

$f_1 = 2_1 B_1$

$f_2 = 2_2 B_2$

$n_2 \perp f_2$

$\Sigma_1 \equiv n_1$

$n_2 \cap (3_2 - 4_2) = K_2$

Figure 2.9 – Determining the distance from point D to the plane ABC of the general position

The algorithm for solving the problem:

1. The main lines of plane ABC are constructed: h – horizontal line, f – frontal line.

2. From point D the projections of the perpendicular n: $n_2 \perp f_2$, $n_1 \perp h_1$ are constructed.

3. The perpendicular axis n is determined by the auxiliary horizontal projection plane Σ, which intersects the compartment along the straight line 3−4. The basis of the perpendicular is a point K whose frontal projection is found on FP: $n_2 \cap (3_2{-}4_2) = K_2$, and K_1 is determined by vertical correspondence.

4. Point to plane projections are projections of the segments D_1K_1 and D_2K_2. The method of a right triangle determines the true length of the segment [DK], which measures the distance from point D to the plane ABC.

2.6 The perpendicularity of the straight line

The right angle between the perpendicular lines of the general position on the projection planes is not projected in full size. The problem of constructing a perpendicular to a straight line of general position is solved by the condition of the perpendicularity of the straight line and the plane.

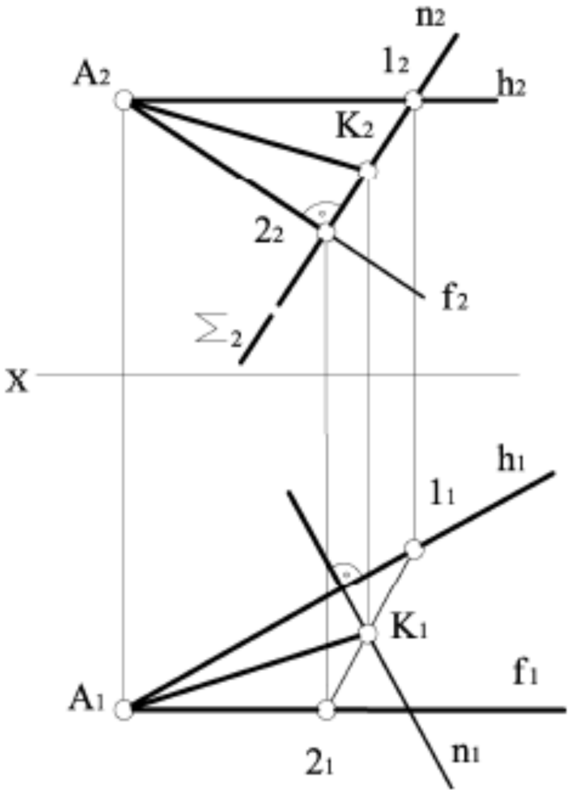
Consider the case of constructing a perpendicular from point A to the direct general position n (Fig. 2.10).

The algorithm for solving the problem:

1. Through point A, the plane θ is perpendicular to the line n: $\theta\ (f \cap h) \perp n$.

2. Determine the point of intersection of the line n with the plane θ. For this purpose, we use the auxiliary frontal projection plane Σ ($\Sigma_2 \equiv n_2$) : $\Sigma_2 \cap \theta_2\ (h_2 \cap f_2) = 1_2 - 2_2$; $(1_1 - 2_1) \cap n_1 = K_1$, and K_2 is determined by vertical correspondence.

3. We connect point A with point K. $AK \perp n$, because this segment belongs to a plane that is perpendicular to the line n. Thus, two straight lines are perpendicular if one of them belongs to a plane that is perpendicular to the other straight line.The perpendicularity of the planes.



$h_2 \parallel ox$

$f_2 \perp n_2$

$h_1 \perp n_1$

$f_1 \parallel ox$

$\theta(h \cap f) \perp n$

$\Sigma_2 \cap (h_2 \cap f_2) = 1_2 - 2_2$

$(1_1 - 2_1) \cap n_1 = K_1$

$AK \perp n$

Figure 2.10 – Construction of a perpendicular line from point A to a straight line of general position n

2.7 The perpendicularity of the planes

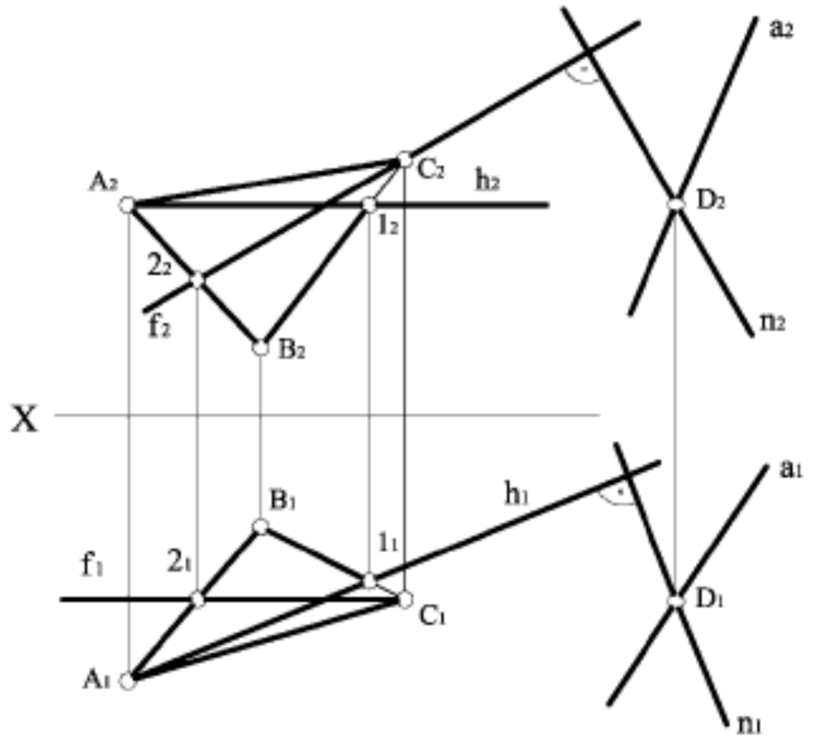
Two planes are perpendicular to each other's if one of those belongs to a straight line that is perpendicular to the other plane.

The construction of the plane P, which is perpendicular to the plane θ, can be done in two ways:

1. The plane P is constructed through a line m that is perpendicular to the plane θ: $(m \perp \theta)$, $(m \in P) \Rightarrow P \perp \theta$.

2. We construct the plane P perpendicular to the line n, which lies in the plane Q or parallel to this plane: $(n \parallel \theta)$, $(n \perp P) \Rightarrow P \perp \theta$, since through the line m it is possible to draw many planes (the first way). In the plane or parallel to plane, it is possible to draw many lines n (the second way), the problem has many solutions. Additional solutions must be imposed for a single solution.

Figure 2.11 shows an example of construction in a complex drawing for a given plane P (ΔABC) from point D perpendicular to the plane θ.



$$a \in \theta, D \in a$$
$$n_2 \perp f_2$$
$$n_1 \perp h_1$$
$$D \in n$$
$$\theta(n \cap a)$$
$$P \perp \theta$$

Figure 2.11 – Complex drawing of the plane P (ΔABC) and the perpendicular plane θ, constructed from point D

The algorithm for solving the problem:

1. The main lines of plane ABC are constructed: h – horizontal, f – front.

2. From point D, we construct a line n that is perpendicular to the plane of the ABC: $n_2 \perp f_2$, $n_1 \perp h_1$.

3. Through point D we construct a straight line a of the general position: P (ABC) ⊥ θ(n ∩ a).

LECTURE 3 PROJECTION PLANE REPLACEMENT METHOD

3.1 Projections on auxiliary planes.

3.2 Finding the true length of the lines.

3.3 Method of rotation around the axis perpendicular to a projection plane.

The essence of a projection plane replacement method is that a position of the depicted points, lines, plane figures in space remains constant, and the system of planes HP, FP supplemented by new planes that make up from an HP1 or FP1 with each other the systems of two mutually perpendicular planes which are considered to be projection planes.

Every new system of projection planes is selected to get a position that is the most convenient to make the necessary construction.

A projection plane replacement method is using for solving different problems is based on four main problems.

3.1 Projections on auxiliary planes

Sometimes none of the three principal orthographic views of an object show the different edges and faces, lanes and planes of an object in their true sizes, since these edges and faces, are not parallel to any one of the three principal planes of projection. In order to show such edges and faces, lanes and planes in their true sizes, it becomes necessary to set up additional planes of projection other than the three principal planes of projection in the positions which will show them in true sizes. If an edge or a face is to be shown in true size, it should be parallel to the plane of projection. Hence the additional planes are set up so as to be parallel to the edges and faces, lanes and planes which should be shown in true sizes. These additional planes of projection which are set up to obtain the true sizes are called auxiliary planes.

The types of planes are shown in Figure 3.1.

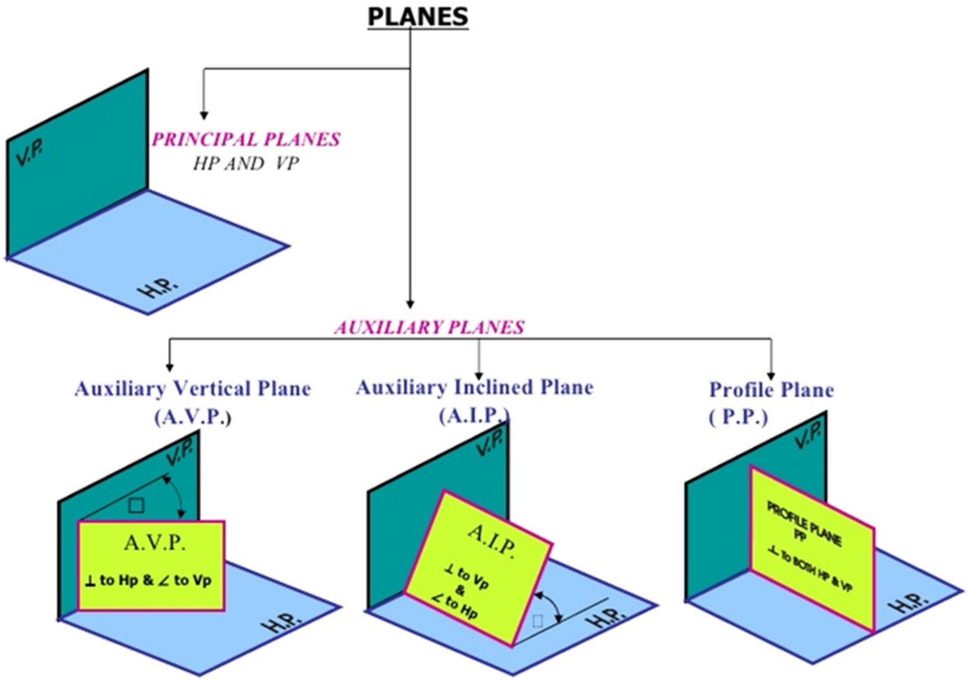


Figure 3.1 – Types of planes

Auxiliary planes are used to determine:

- true shape of inclined or oblique surfaces;
- visibility of lines and planes;
- shortest distance between two lines;
- shortest distance from point to plane;
- slope of line or plane;
- angle between two planes;
- intersection of two planes.

Usually the auxiliary planes are set up such that they are parallel to the edge or face which is to be shown in true size and perpendicular to any one of the three principal planes of projection. Therefore, the selection of the auxiliary plane as to which of the principal planes of projection it should be perpendicular, obviously depends on the shape of the object whose edge or face that is to be shown in true size.

If the auxiliary plane selected is perpendicular to HP and inclined to FP (VP), the view of the object projected on the auxiliary plane is called auxiliary front view and the auxiliary plane is called auxiliary vertical plane and denoted as AFP (AVP).

If the auxiliary plane is perpendicular to VP and inclined to HP, the view of the object projected on the auxiliary plane is called auxiliary top view and the auxiliary plane is called auxiliary inclined plane and denoted as AIP.

Auxiliary frontal plane (AFP). An AFP is placed in the first quadrant with its surface perpendicular to HP and inclined at φ to FP. The object is assumed to be placed in the space in between HP, FP and AFP. The AFP intersects HP along the X_1Y_1 line. The direction of sight to project the auxiliary front view will be normal to AVP. The position of the auxiliary vertical plane is shown in Figure 3.2.

After obtaining the top view, front view and auxiliary front view on HP, FP and AFP, the HP, with the AFP being held perpendicular to it, is rotated as to be in plane with that of FP, and then the AFP is rotated around line X_1Y_1 as to be in position plane with rotated HP.

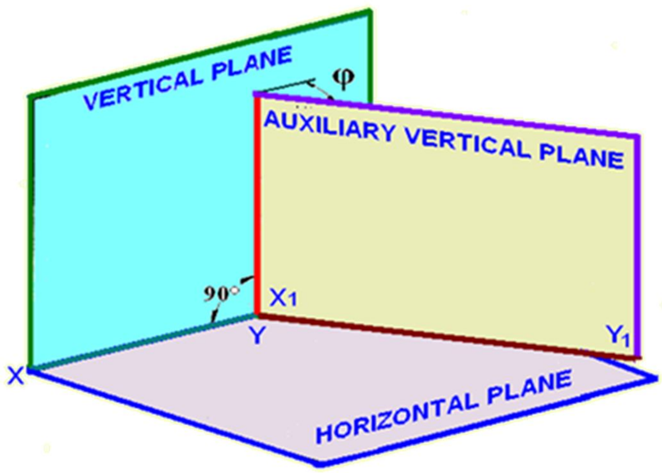


Figure 3.2 – The position of the auxiliary vertical plane

Auxiliary inclined plane (AIP). AIP is placed in the first quadrant with its surface perpendicular to VP and inclined at q to HP. The object is to be placed in the space between HP, FP and AIP. *The* AIP intersects the FP along the X_1Y_1 line. The direction of sight to project the auxiliary top view will be normal to the AIP. The position of the AIP with respect to HP and VP is shown in Figure 3.3.

After obtaining the top view, front view and auxiliary top view on HP, FP and AIP, HP is rotated about the XY line independently (detaching the AIP from HP). The AIP is then rotated about X_1Y_1 line independently so as to be in-plane with that of FP.

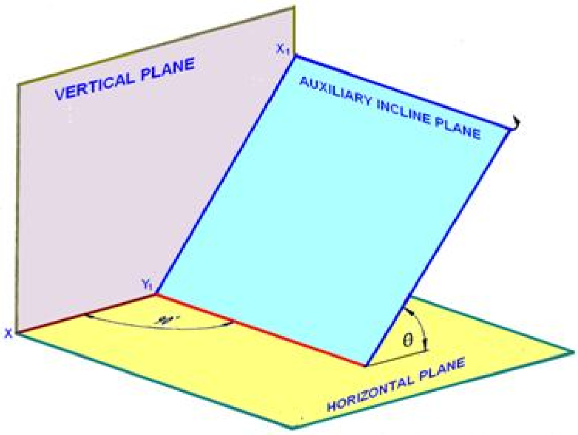


Figure 3.3 – The position of the auxiliary inclined plane with respect to HP and FP

3.2 Projection of points on auxiliary plane

Point on the Auxiliary plane is shown in Figure 3.4.

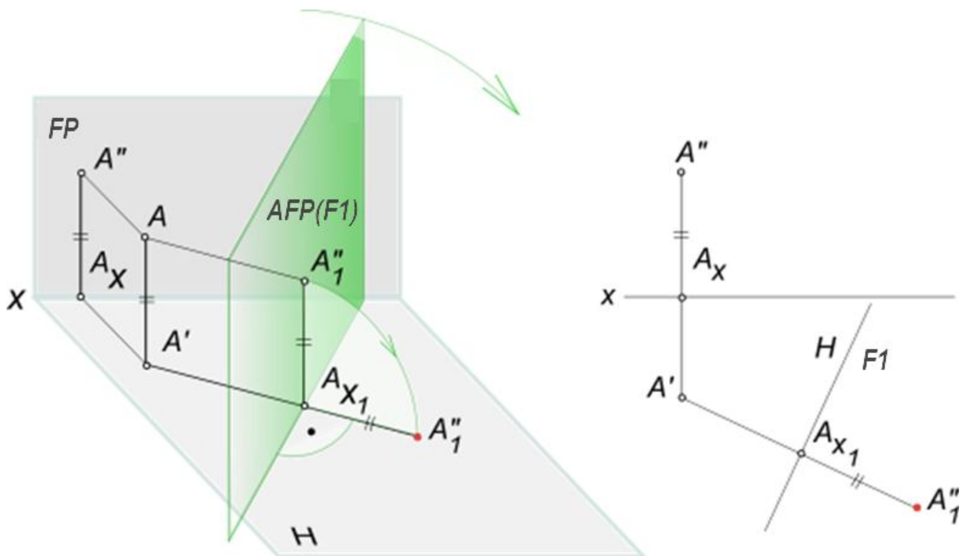


Figure 3.4 – Projection of point A on the auxiliary plane

3.3 Finding the true length of the line

The length of a line can only be measured if it is seen in true length.

A line can be seen true length if projected onto a plane parallel to it. Therefore, to find the true length of a line we draw an auxiliary folding line parallel to it (Fig. 3.5). Distances for the new points of new plane are taken from the frontal plane of the projections and set aside from the new axis X_1.

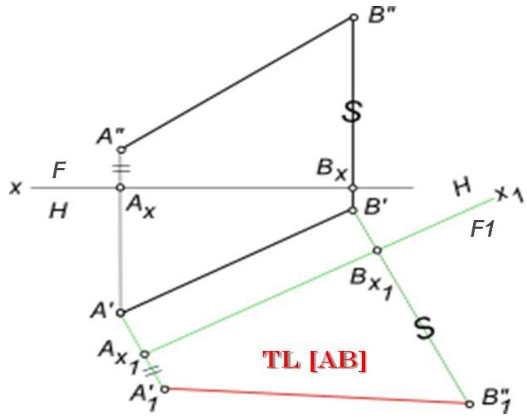


Figure 3.5 – The line AB on the auxiliary plane

3.4 Projections on auxiliary planes

The true size of a plane on the auxiliary plane is shown in Figure 3.6.

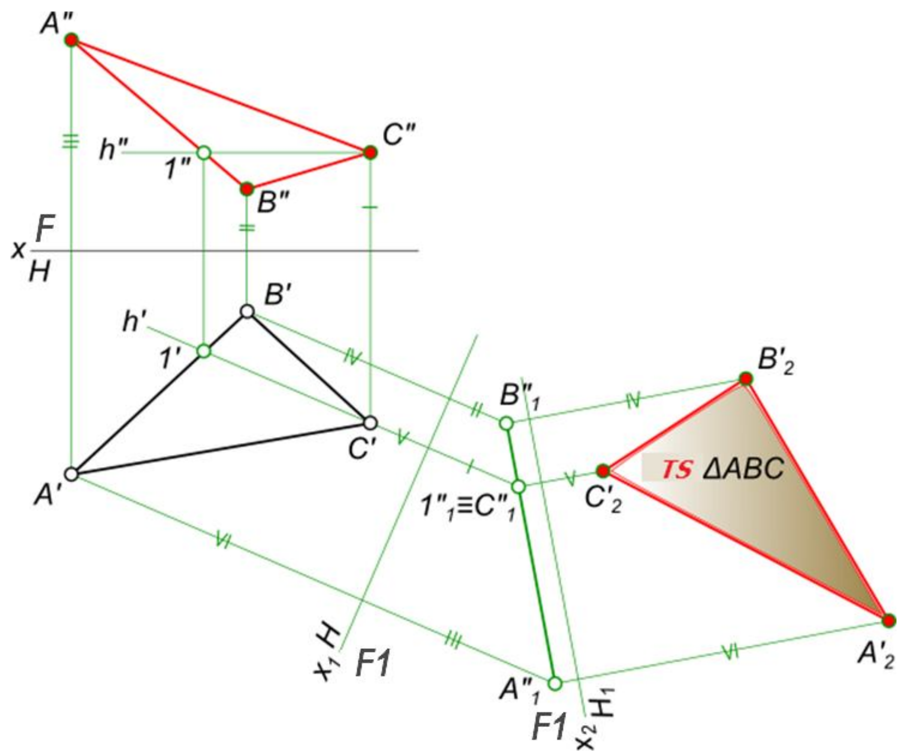


Figure 3.6 – The plane of triangle ABC on the auxiliary plane

Problem. Determine the distance from point A to plane α. On Figure 3.7 plane α of a general position is specified by triangle.

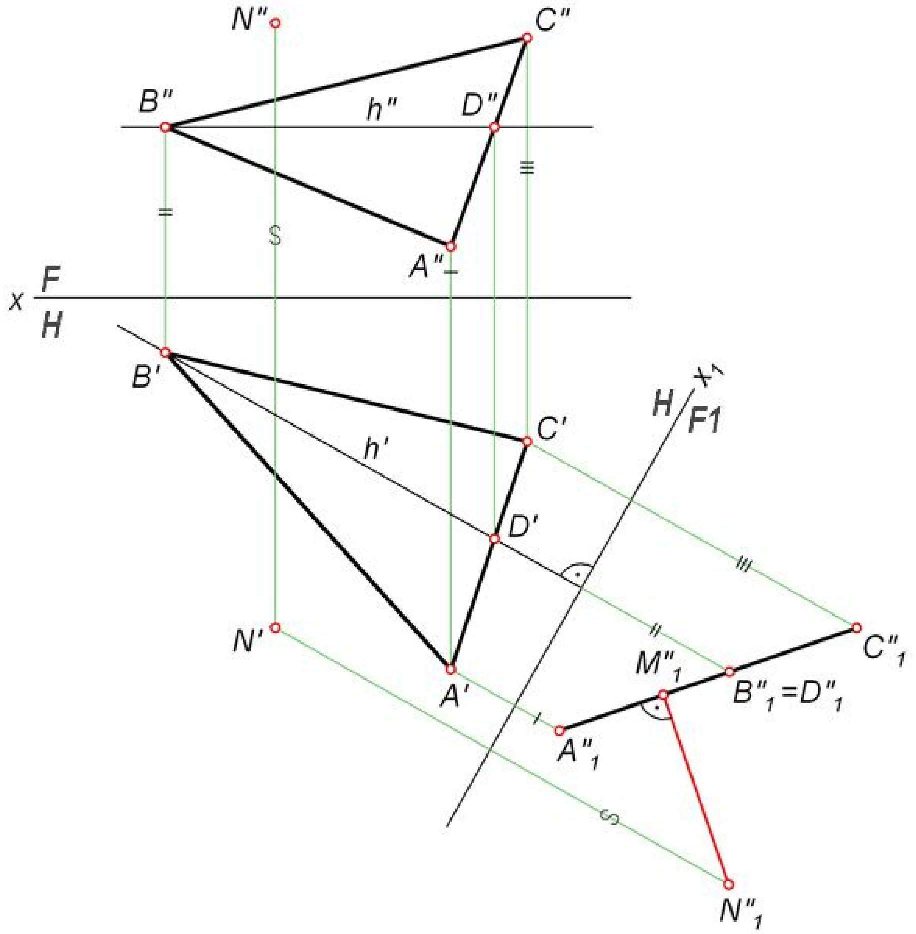


Figure 3.7 – Distance from point N to plane of triangle ABC on the auxiliary plane

The algorithm for solving the problem:

1. Construct the level line h of triangle ABC.

2. Draw an auxiliary projection plane AFP (F_1) perpendicular of level line h. New axis X_1 is perpendicular of h_1.

3. From projection of point N (N''_1) draw perpendicular line to new projection of triangle on auxiliary plane AFP (F_1).

LECTURE 4 SURFACES and MULTIVIEW DRAWINGS

4.1 Polyhedrons.

4.2 Curved surfaces.

4.3 The intersection of the surfaces.

4.4 Multiview drawings.

4.5 Rules of design drawings.

4.6 Sections.

A surface is a geometric place of the consistent positions of lines (generating lines), that are moved in space according to a certain law (a guiding line). A surface that is constructed due a law of the generating lines movement is called a logical surface, unlike an accidental surface. On any kinematic surface there are two types of lines: generating lines and guiding lines that can exchange their roles. Therefore, one surface can be made up by the movement of different lines. If a generating line of a surface is a straight line, a surface is called a rectilinear surface. If a generating line of a surface is a curve, a surface is called a curvilinear surface.

A straight cylinder (Fig. 4.1) is formed when both guidelines are smooth curves, one of which belongs to a plane perpendicular to the plane of parallelism. If one of the guides is a straight line, then a straight conoid is formed (Fig. 4.2); if the guides are passing lines, a hyperbolic paraboloid is formed (Fig. 4.3).

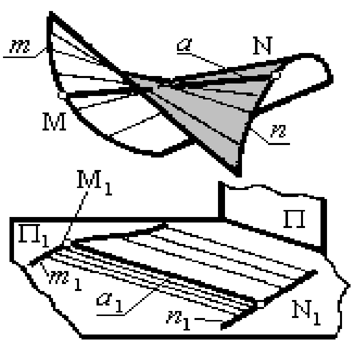


Figure 4.1 –
A cylindroid

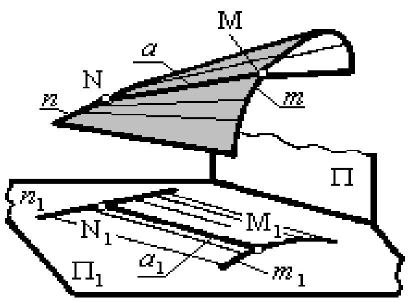


Figure 4.2 –
A conoid

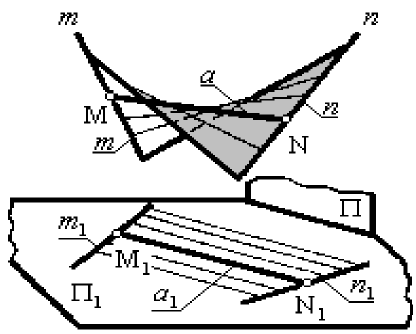


Figure 4.3 –
A hyperbolic paraboloid

There are two basic types of solids: polyhedrons and curved solids.

Dimensional parameters of different surfaces are shown in Figure 4.4.

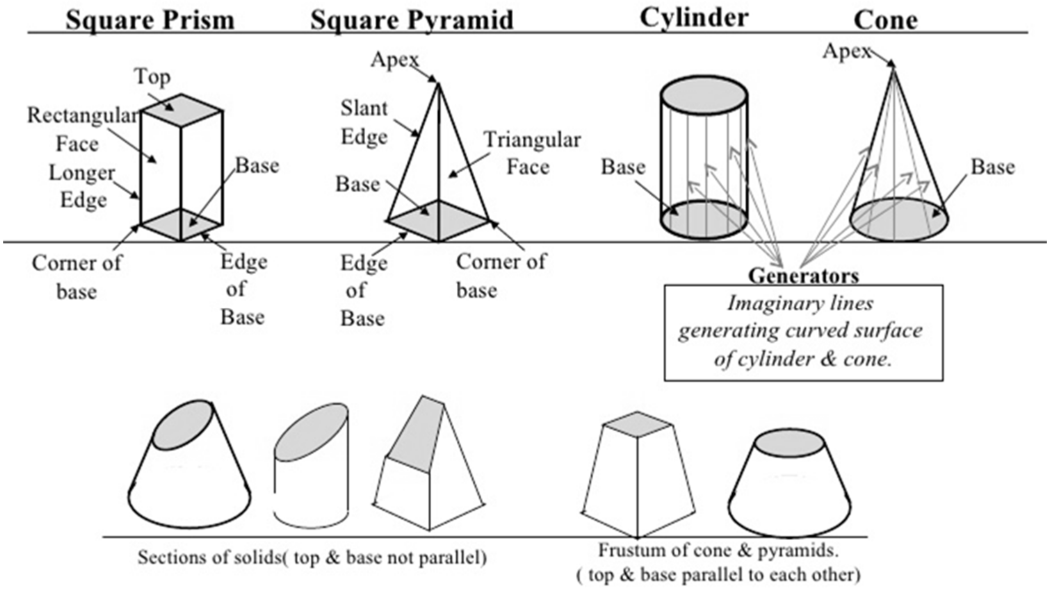


Figure 4.4 – Dimensional parameters of different surfaces

4.1 Polyhedrons

Polyhedrons are very general shapes. Even shapes that are not polyhedra can be simulated by polyhedra. So what are they? Polyhedra are three-dimensional objects made of polygons. Polygons are two-dimensional objects made of straight lines; they can be squares, rectangles, triangles, nonagons, etc.

There are three vocabulary words that are important to remember in order to understand what polyhedrons are: faces, edges, and vertices. Faces are the flat parts of the polyhedral – they are the polygons. Edges are the line where two faces meet. Vertices are the points where three or more faces meet. A cube, displaying face, vertex, and edge (Fig. 4.5).

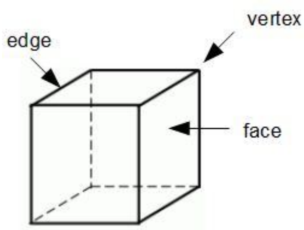
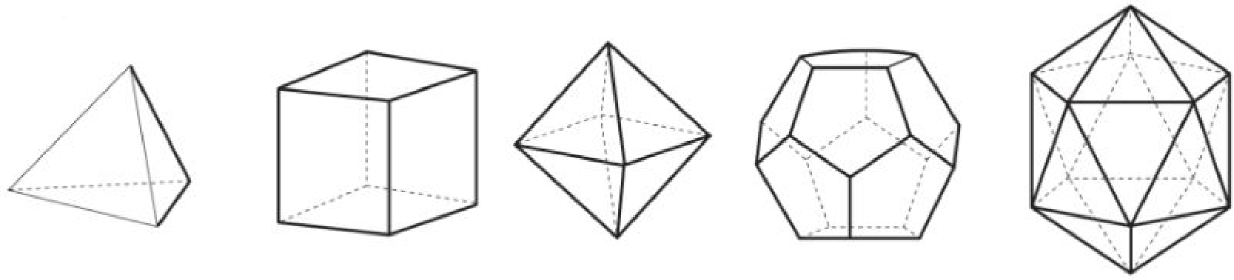


Figure 4.5 – Elements of polyhedron

In fact, there is a mathematical relationship between these three terms, known as Euler's Polyhedron Formula. It states that the vertices, edges, and faces satisfy the equation: Vertices - Edges + Faces = 2.

A solid bounded by equal and regular plane surfaces is known as regular polyhedron like tetrahedron (Fig. 4.6, a), hexahedron (Fig. 4.6, b), octahedron (Fig. 4.6, c), dodecahedron (Fig. 4.6, d), and icosahedron (Fig. 4.6, e).



a) b) c) d) e)

Figure 4.6 – Regular polyhedrons

Prism and pyramids are also other types of polyhedral.

A prism is a polyhedron having two equal and parallel geometrical-shape ends or bases. These two bases joined by rectangular faces (Fig. 4.7, 4.8, 4.9).

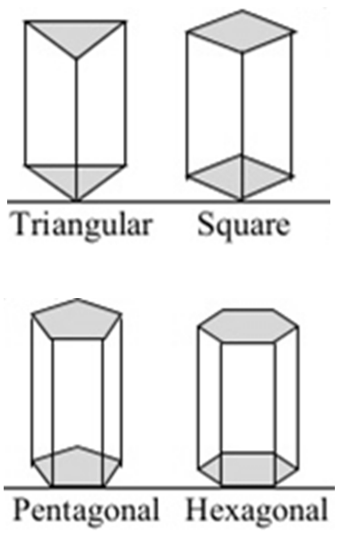


Figure 4.7 – Prisms

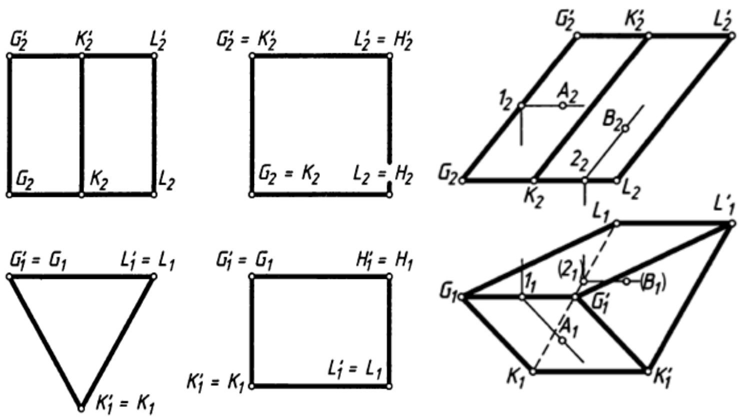


Figure 4.8 – Two projection views of triangular prism, square prism and triangular inclined prism

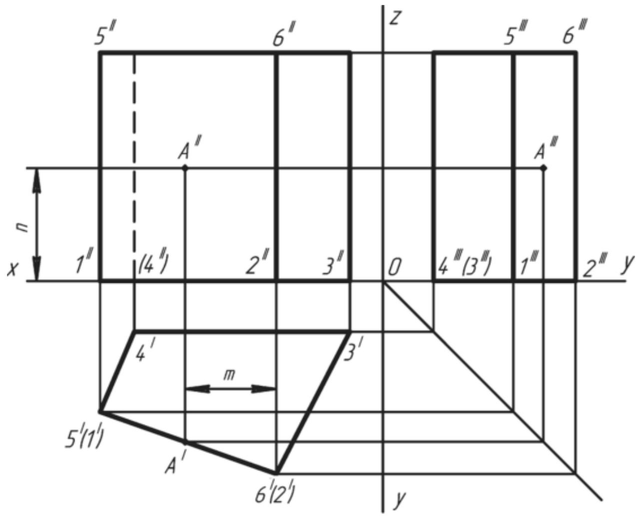


Figure 4.9 – Projection drawing of prism

A pyramid is a polyhedron having one geometrical base and a number of isosceles triangles as faces meeting at a point called the vertex or apex. The axis of the pyramid can be obtained by joining the center of the base and the apex of the pyramid as shown in the Figure 4.10, 4.11.

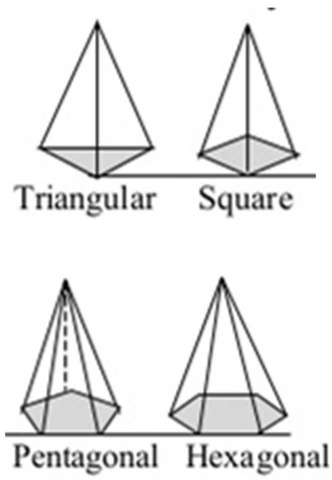


Figure 4.10 – Prisms

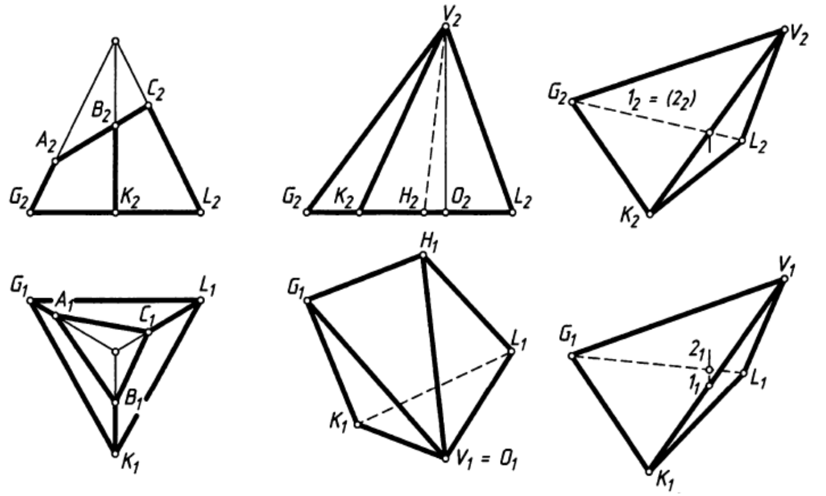


Figure 4.11 – Two projection views of different types of prisms

To construct projections of points lying on the surface of a polyhedron, it is necessary to analyze which part of the surface the point belongs to, how this part is projected on the plane of projections, and then build an image of the point (Fig. 4.11).

The points located on the edges and faces of a straight prism are found by their belonging to these elements (Fig. 4.11).

4.2 Curved surfaces

Curves solids are solids those boundary contains some curved surfaces.

Regular curved surfaces are sphere (all points on the surface are equidistant from the center), ellipsoid (a form whose plane surfaces are either ellipses or circles), ovoid and torus (a rounded form on a circular base in the case of a circle, resembling a doughnut).

Cone is a solid with a circular base connected by a curved surface to a single vertex (Fig. 4.12).

Cylinder is a solid with congruent parallel circular bases connected by a curved surface (Fig. 4.13).

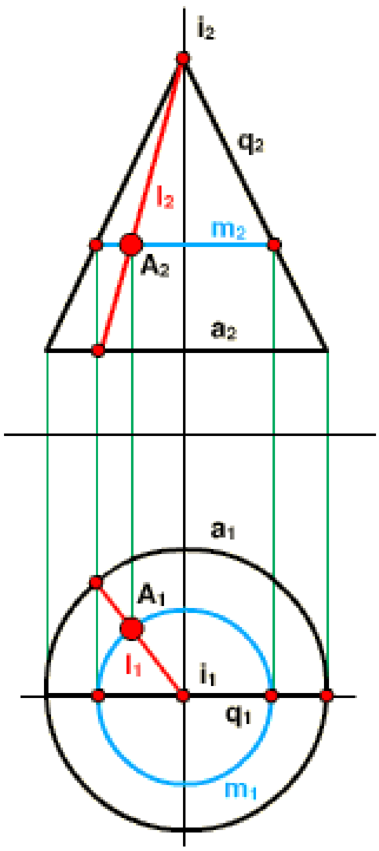


Figure 4.12 – Projection of cone

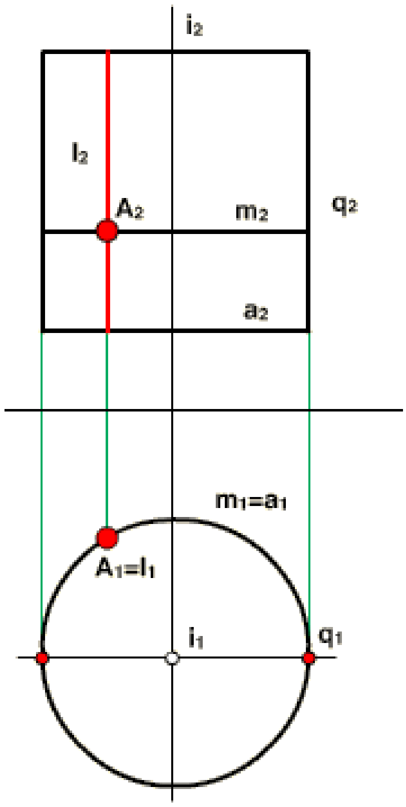


Figure 4.13 – Projection of cylinder

Sphere is set of points in space that are the same distance from a given point. A sphere has no faces, edges, or vertices (Fig. 4.14).

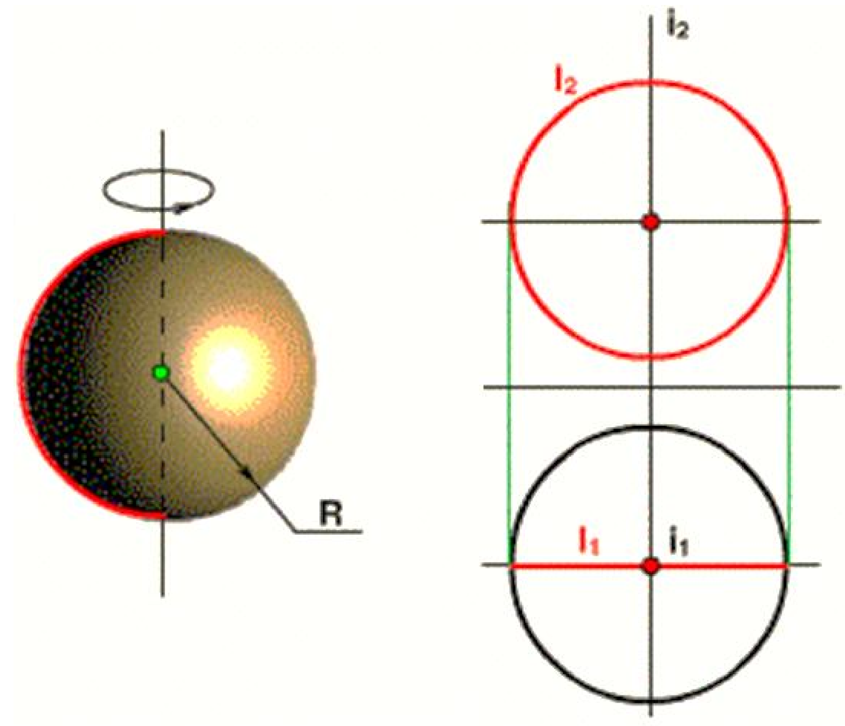


Figure 4.14 – Projection of sphere

4.3 The intersection of the surfaces

The line of intersection of two polyhedral is one or two closed zigzag lines. The segments of the zigzag line are the lines of intersection of the faces, and the breakpoints are the points of intersection of the edges of one polyhedron with the faces of another and the edges of the second with the faces of the first one. If one polyhedron partially intersects another, then the line of intersection will be one closed broken line. This intersection is called incomplete line. If one polyhedron completely intersects another, then the intersection is called complete, and the line of intersection consists of two closed zigzag lines.

The points of intersection of the edges of the pyramid with the prism (Fig. 4.15) are easily determined on the horizontal projection. We use front lines to build frontal projections of these points. Of the vertical edges of the prism, only one edge intersects the pyramid. The points of intersection of this edge with the faces of the pyramid are determined by passing the auxiliary horizontal projection plane Δ through the edge and the top of the pyramid. It intersects the faces of the pyramid along the lines that intersect the edge of the prism at points T_2 and Q_2. We connect the constructed projections of points by segments of lines within each face, guided by a horizontal projection. The line of intersection is two closed zigzag lines. The section is complete. Visible are those sections of the line of intersection that belong to the visible faces of polyhedral.

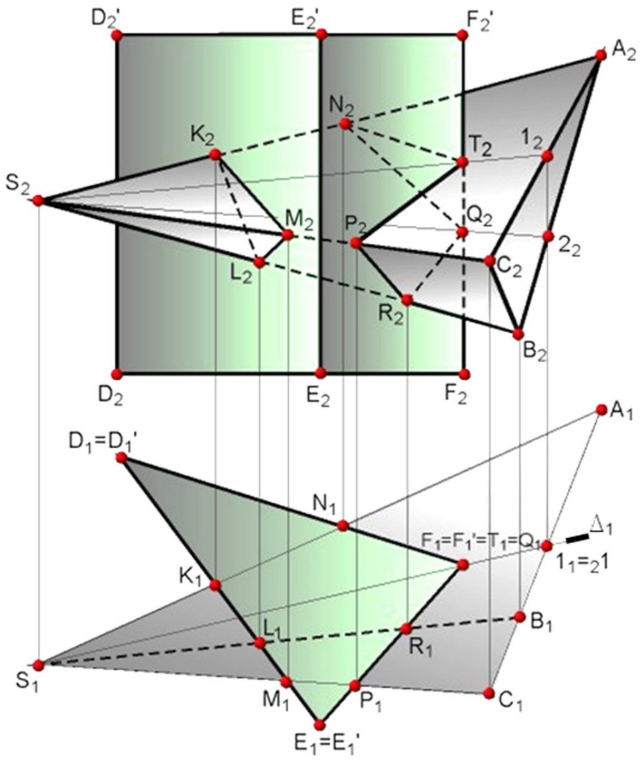


Figure 4.15 – Construction of the intersection line of the surfaces of a straight prism and a pyramid

The projections of the line of intersection can be located only within the overlap of the outlines of the projections of the intersecting surfaces of the same name. Therefore, it is desirable to find in both polyhedra such edges that consciously do not participate in the intersection.

4.4 Axonometric projection

Axonometric projection is a method of drawing with instruments which gives a pictorial view of an object. It is not often used in industry and, when it is, the vast majority of drawings are made using conventional axonometric projection.

An additional condition of this projection, which ensures the reversibility of the drawing, is a rectangular coordinate system, which is called natural. The main advantage of these projections is visual presentation.

Conventional isometric projection is a distorted and simplified form of true axonometric. True isometric is found by taking a particular view from an orthographic projection of an object.

Axonometric projections of the object (A) together with the natural coordinate system (O_{xyz}) on one plane (P') of projections are called (Fig. 4.16).

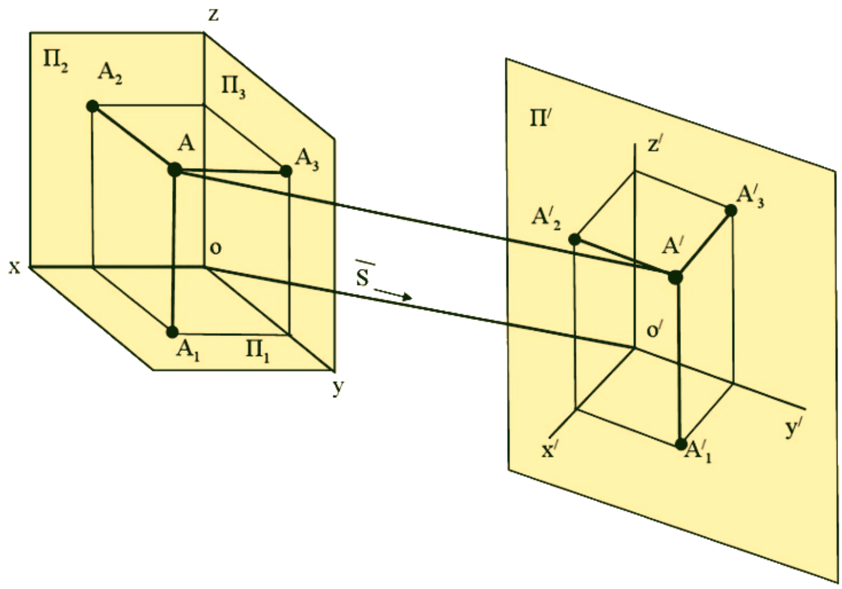


Figure 4.16 – Formation of an axonometric view

The three isometric axes are still at 120° to each other. In conventional isometric, distances measured parallel to these axes are true lengths. In true isometric projection they are no longer true lengths although they are proportional to their true lengths. However, the horizontal distances on a true isometric projection are true lengths. The reduction of lengths measured parallel to the isometric axes makes the overall size of the true isometric drawing appear to look more natural, particularly when directly compared with an orthographic or plane view of the same object.

Isometric drawing ignores perspective altogether. Lines are drawn parallel to each other and drawings can be made using a T-square and a set square. Figure 4.17 shows a shaped block drawn in conventional isometric projection.

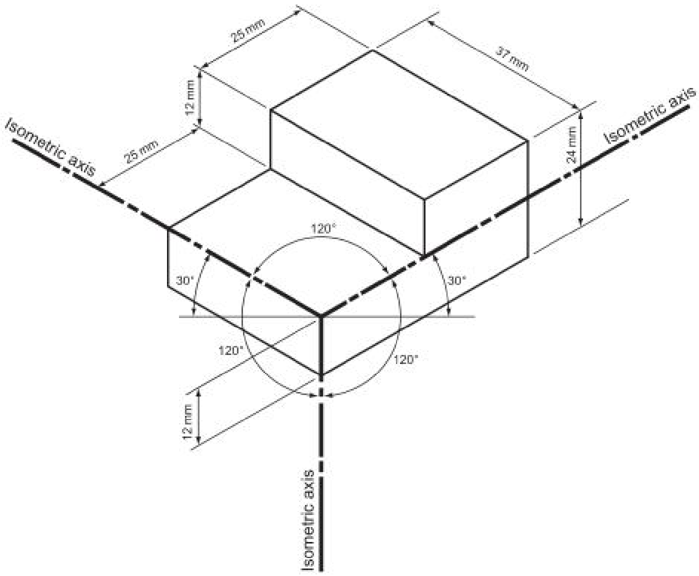


Figure 4.17 – Shaped block drawn in conventional isometric projection

You will note that there are three isometric axes. These are inclined at 120° to each other. One axis is vertical and the other two axes are therefore at 30° to the horizontal. Dimensions measured along these axes, or parallel to them, are true lengths.

Examples of the arrangement of the axonometric axes of isometric projection (Fig. 4.18) and dimetric projection (Fig. 4.19) are illustrated.

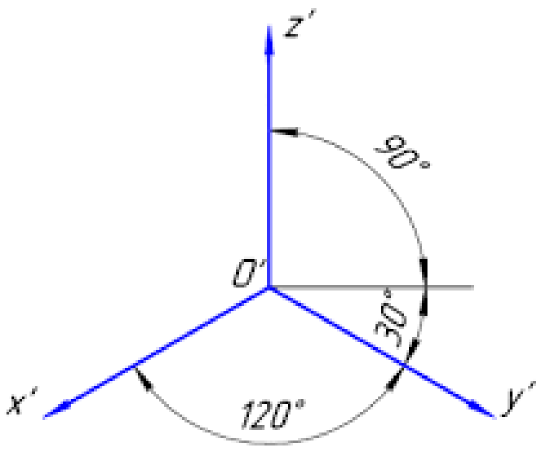


Figure 4.18 – Axes
of isometric projection

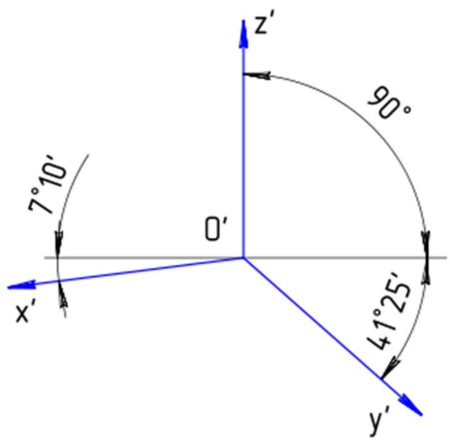


Figure 4.19 – Axes of
dimetric projection

To construct an axonometric projection of point A on the plane P 'it is necessary to project not only point A, but also one of its orthogonal projections (usually horizontal projection A_1). The axonometric projection A_1' of the horizontal projection of point A is called the secondary projection (Fig. 4.20).

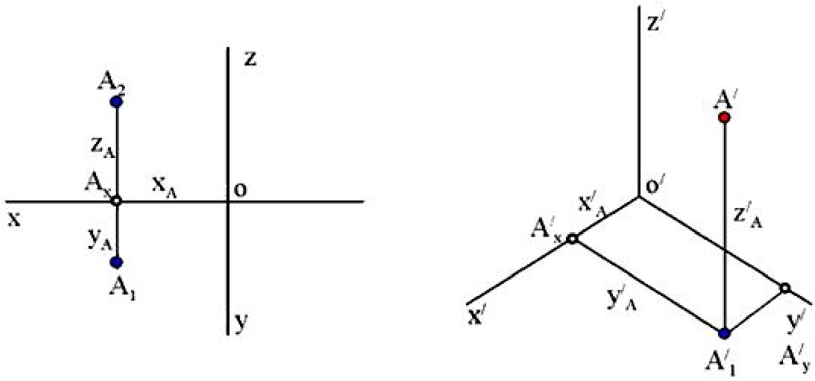


Figure 4.20 – Construction of axonometric projection of point A

Axonometric of faceted surfaces

Figure 4.21 shows the construction of a regular triangular pyramid in rectangular isometry and rectangular dimetric by the secondary horizontal projection. If one face of the surface coincides with the coordinate plane (in the proposed example, the base A'B'C' lies in the plane x'O'y'), then the secondary projections of the vertices are not indicated.

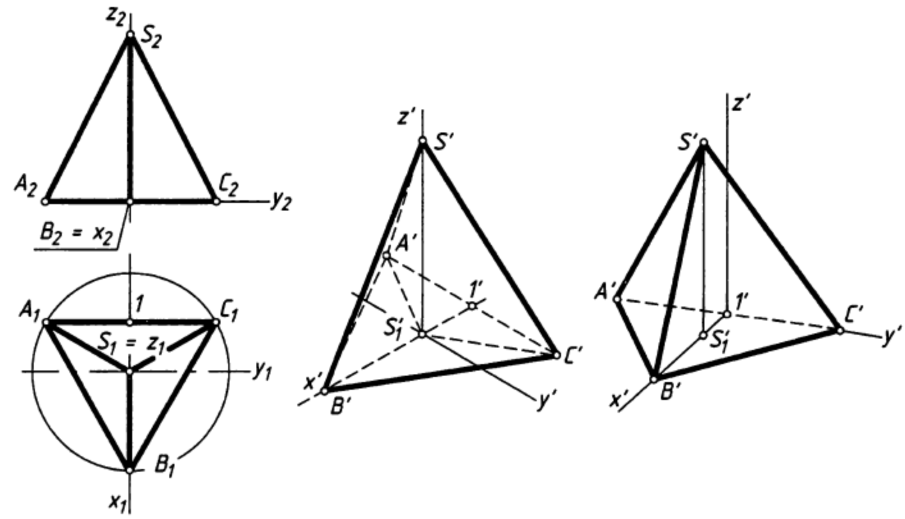


Figure 4.21 – Construction of a pyramid in isometry and dimetry

When constructing a hexagonal prism (Fig. 4.22), the vertices D', A' are marked along one of the axes. Then the edges C'B', E'F' draw parallel to the same axis. A side edge is built from each vertex and the vertices are connected by the edges of the base (Fig. 4.22).

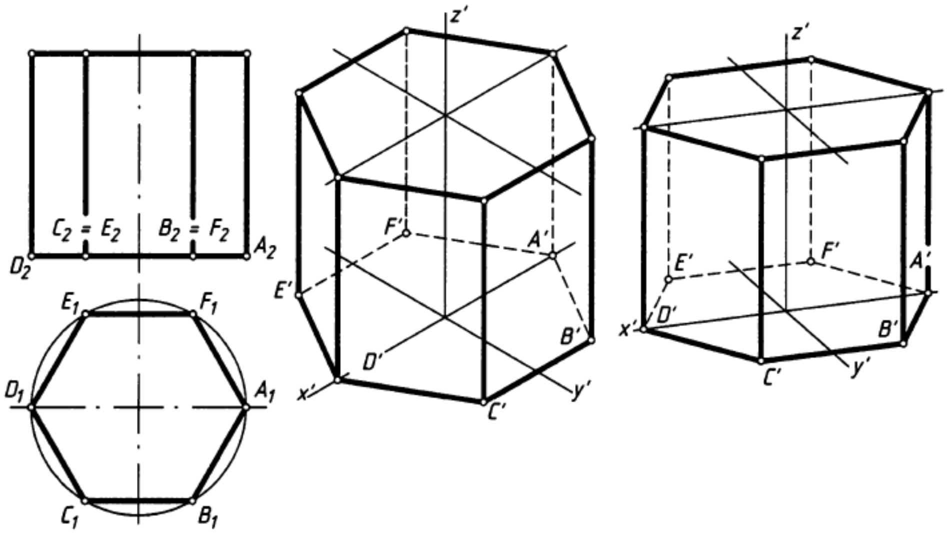


Figure 4.22 – Construction of a hexagonal prism in isometry and dimetry

4.5 Multiview drawings

The plane of projection can be oriented to produce an in-finite number of views of an object. However, some views are more important than others. These principal views are the six mutually perpendicular views that are produced by six mutually perpendicular planes of projection. If you imagine suspending an object in a glass box (Fig. 4.23) with major surfaces of the object positioned so that they are parallel to the sides of the box, the six sides of the box become projection planes showing the six views.

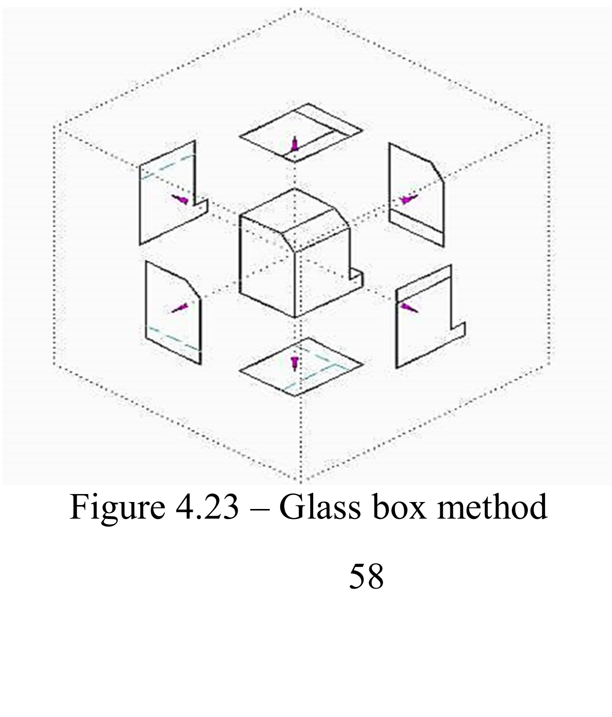


Figure 4.23 – Glass box method

The six principal views are front, top, left side, right side, bottom, and rear (Fig. 4.24). Unfolding the box produces an arrangement of the six views.

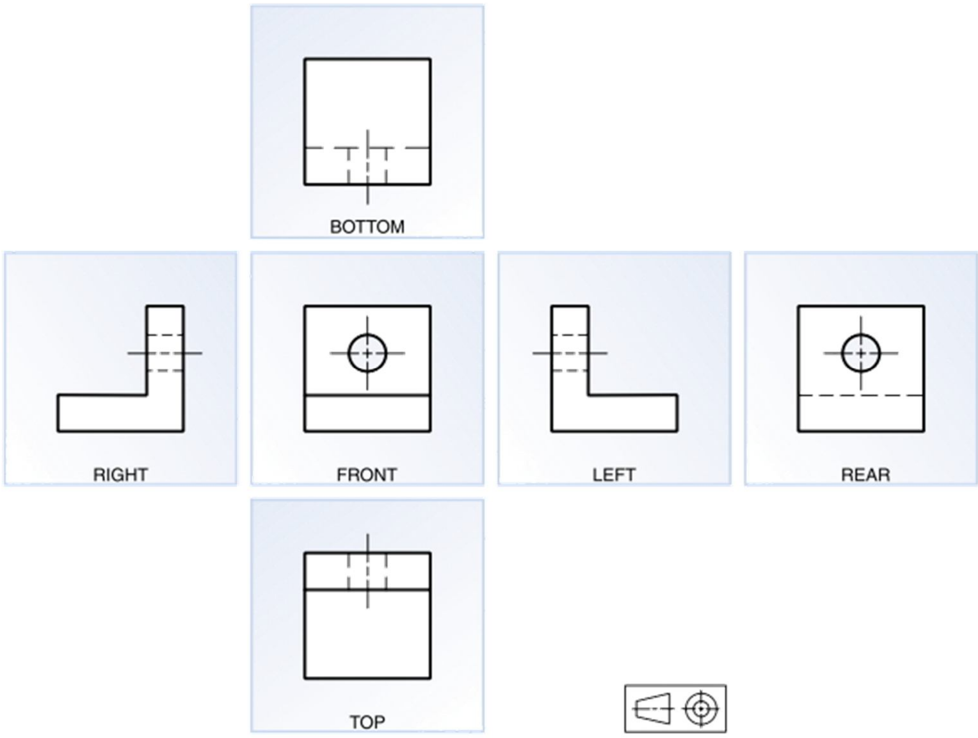


Fig. 4.24 – Glass box being unfolded

The front view of an object shows the width and height dimensions. The frontal plane of projection is the plane onto which the front view of a multiview drawing is projected.

Multiview drawings employ multiview projection techniques. In multiview drawings, generally, three views of an object are drawn, and the features and dimensions in each view accurately represent those of the object. The views are defined according to the positions of the planes of projection with respect to the object.

Object is projected onto planes from the first angle or quadrant:

- front view projected to vertical plane;
- top view projected to horizontal plane;
- left-side view projected to profile plane.

In multiview drawings, generally, three views of an object are drawn, and the features and dimensions in each view accurately represent those of the object. The views are defined according to the positions of the planes of projection with respect to the object (Fig. 4.25).

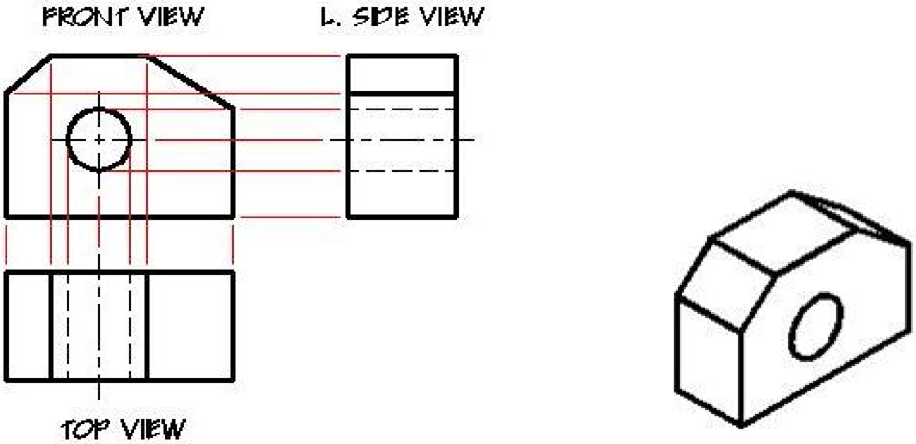


Figure 4.25 – Three views and isometric view of the object

Some objects can be adequately described with only one view. One-view drawings are used in electrical, civil, and construction engineering. Other objects can be adequately described with two views. Cylindrical, conical, and pyramidal shapes.

Figure 4.26 shows an example of constructing an axonometric projection of a hexagonal prism.

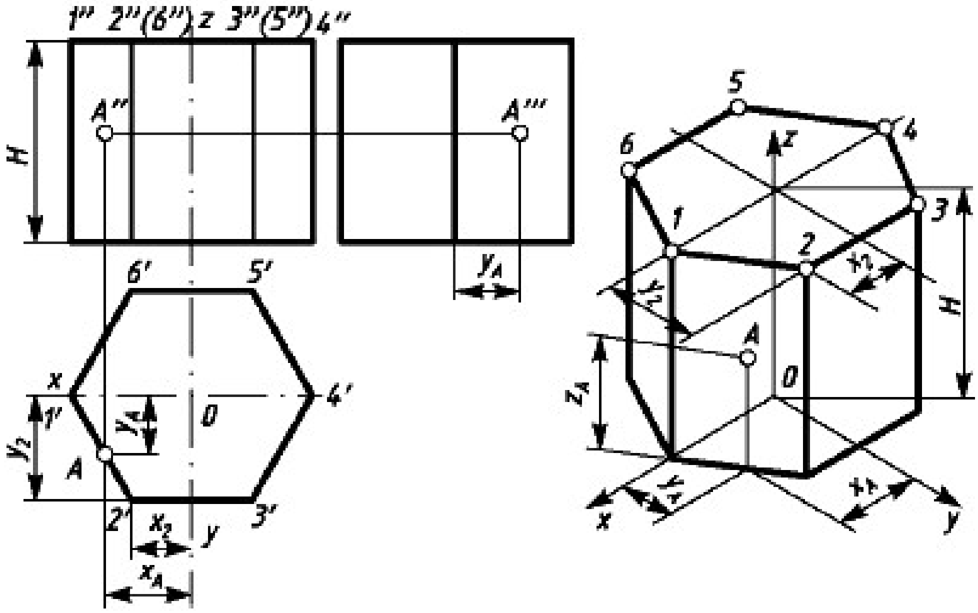


Figure 4.26 – Example of constructing an multiview drawing and axonometric projection of a hexagonal prism and a point A belonging to this surface

4.6 Rules of design drawings

Paper sizes

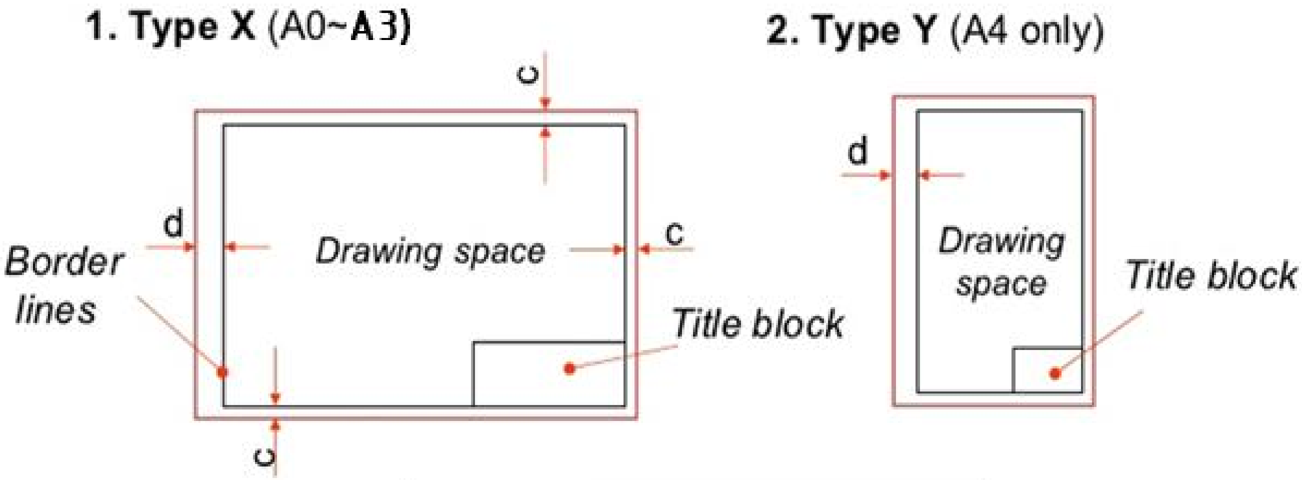
Depending on the size of the object, it is placed on standard drawing sheets. The International Standards Organization (ISO) system of paper sizes applies to all grades of paper and paper board and consists of five series of sizes: A, RA, SR, B, and C. Paper series of sizes A, B, and C are shown in Table 4.1.

Table 4.1 – The width and height of ISO A, B and C paper formats

A sizes (mm)		B sizes (mm)		C sizes (mm)	
4A0	1682 x 2378	-	-	-	-
2A0	1189 x 1682	-	-	-	-
A0	841 x 1189	B0	1000 x 1414	C0	917 x 1297
A1	594 x 841	B1	707 x 1000	C1	648 x 917
A2	420 x 594	B2	500 x 707	C2	458 x 648
A3	297 x 420	B3	353 x 500	C3	324 x 458
A4	210 x 297	B4	250 x 353	C4	229 x 324
A5	148 x 210	B5	176 x 250	C5	162 x 229
A6	105 x 148	B6	125 x 176	C6	114 x 162
A7	74 x 105	B7	88 x 125	C7	81 x 114
A8	52 x 74	B8	62 x 88	C8	57 x 81
A9	37 x 52	B9	44 x 62	C9	40 x 57
A10	26 x 37	B10	31 x 44	C10	28 x 40

By placing two sheets of A series paper next to each other, or by cutting one in half parallel to its shorter side, the resulting sheet will again have the same width to height ratio.

There are 2 types of sheet schema location: horizontal (type X) and frontal (type Y) orientations (Fig. 4.27).



Sheet size	c, mm	d, mm
A4	5	20
A3	5	20
A2	5	20
A1	5	20
A0	5	20

Figure 4.27 – Types of sheets location

The title block is placed in bottom right corner of the drawing sheet (Fig. 4.28).

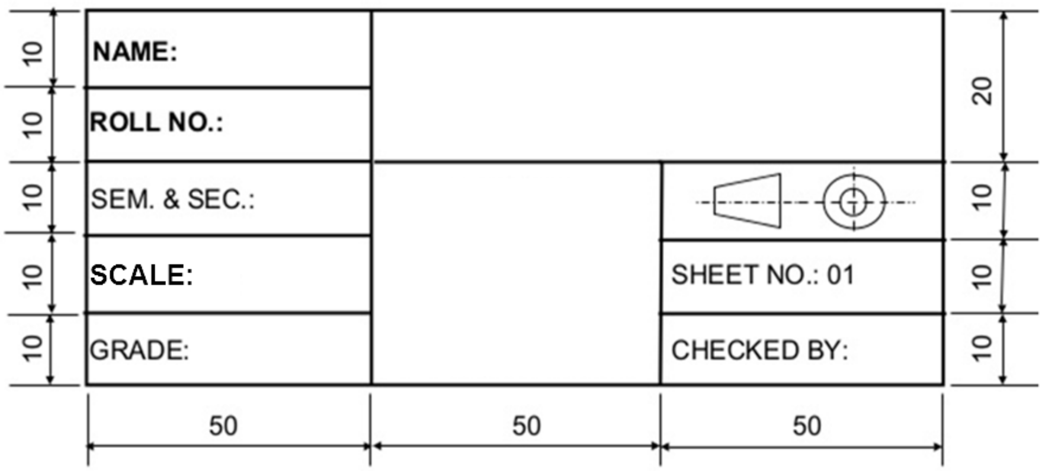
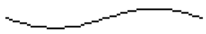
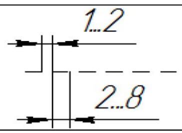
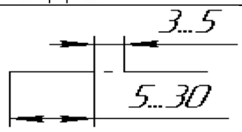
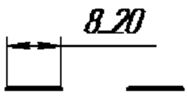


Figure 4.28 – Title block

Basic line types

Line types used in technical drawing are used for different purposes to provide specific information to the people looking at the drawing (Table 4.2).

Table 4.2 – The line types

Line	Illustration	Thickness	Aplication
Continuous thick (object)		S= 0,5 – 1,4 mm Thick	Outlines, visible edges, surface boundaries of objects
Continuous thin		S/3 – S/2 Thin	Dimensions, leader, extensional
Shot break (Continuous thin free hand)		S/3 – S/2 Thin	Limits of partial views or sections when the line is not an axis, interrupted views and sections
Hidden		S/3 – S/2 Thin	Hidden outlines and edges
Center		S/3 – S/2 Thin	Centerlines, lines of symmetry
Chain		S – 1,5 S Extra thick	Cutting planes
Long break with zig-zag		S/3 – S/2 Thin	Indicate of long break

Technical drawing lines are used for different purposes to provide specific information for designers, manufacturers, etc. looking at the drawing. The person who will read drawings have to learn what they mean. Line types are also a language type to communicate between technical people.

4.7 Sections

A section is an image of an object that is conventionally crossed by one or more planes. In this case, the section depicts what is placed in the cutting planes and behind them.

Depending on the position of the cutting plane relative to the horizontal plane of the projections, the sections are divided into:

- horizontal – the cutting plane is horizontal (Fig. 4.29);
- frontal – the cutting plane is vertical (frontal and profile) (Fig. 4.30, 4.31);
- inclined – the cutting plane forms an angle with the horizontal, which differs from the straight line.

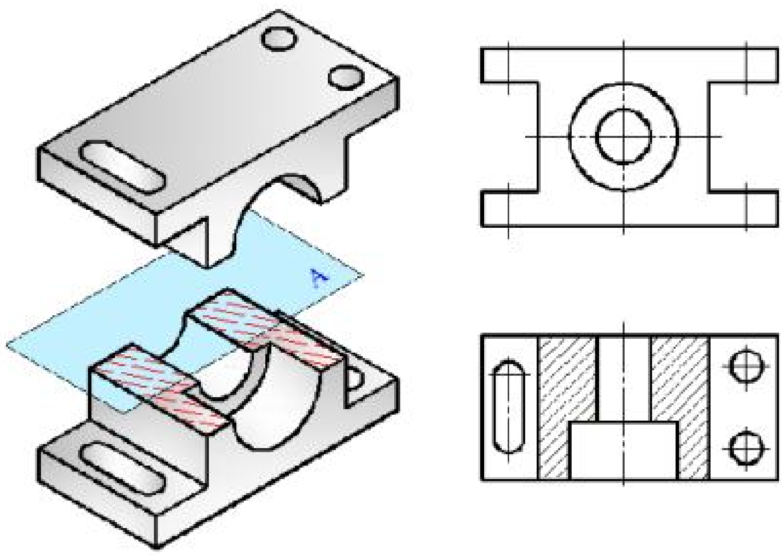


Figure 4.29– Horizontal section

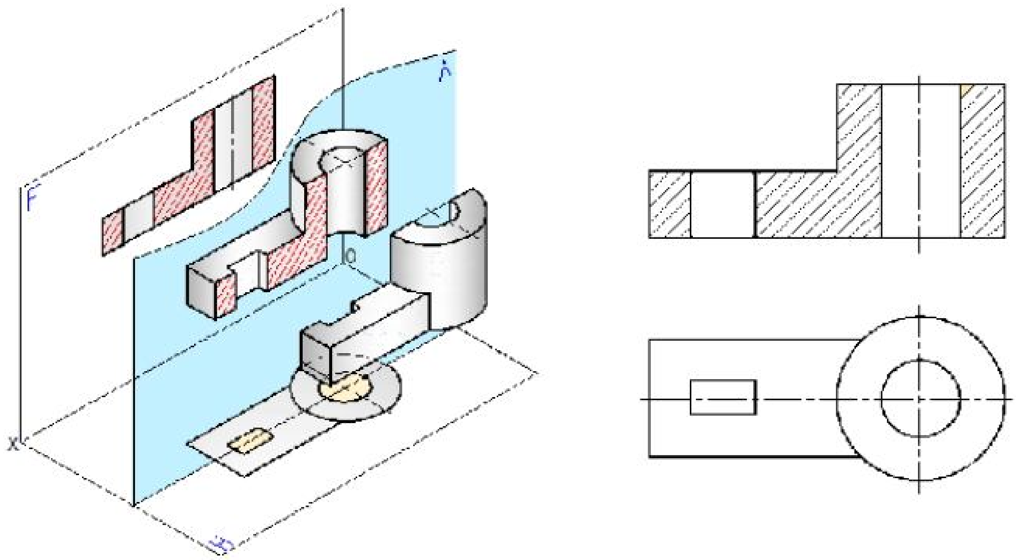


Figure 4.30 – Frontal section

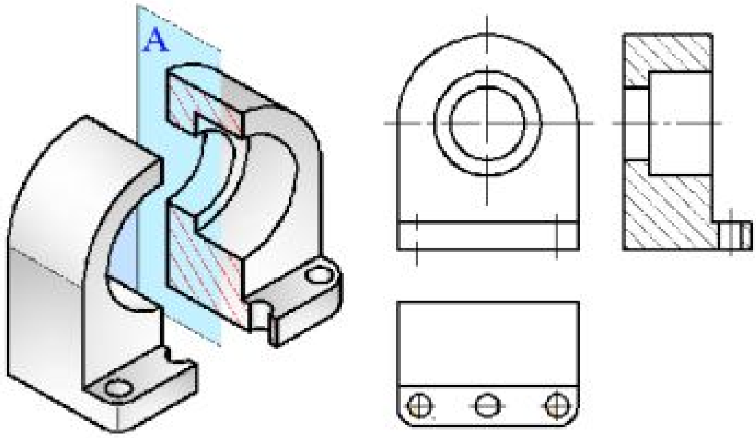


Figure 4.31 – Profile section

Part of the view and part of the section can be connecting by separating them with a wavy line or centerline (Fig. 4.32).

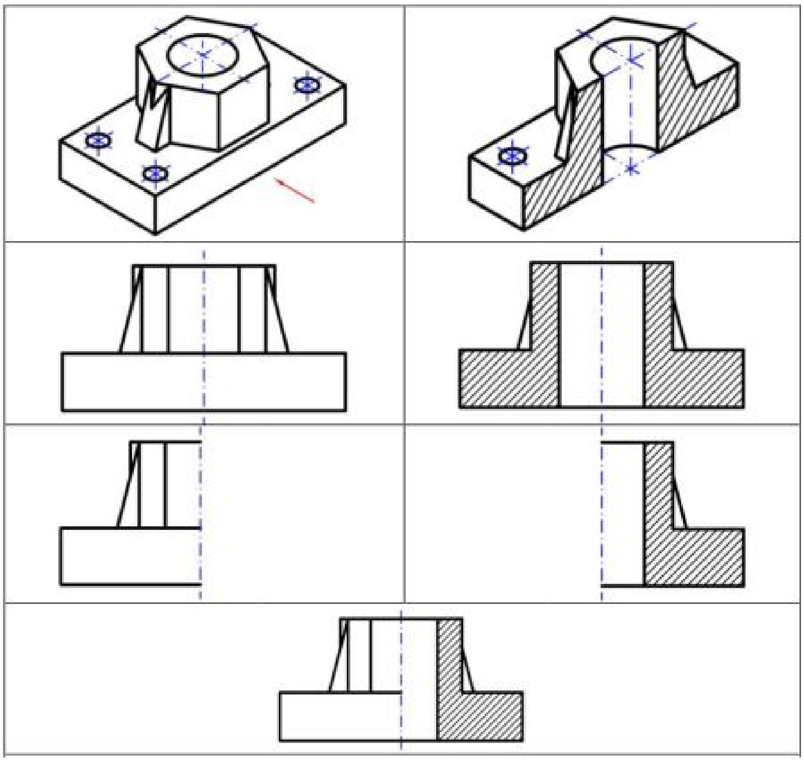


Figure 4.32 – Half view with half of the section

LECTURE 5 2D AND 3D MODELS IN AUTOCAD

5.1 Basic commands for creating 2D-drawings in AutoCAD.

5.2 Basic commands for creating 3D-models in AutoCAD.

5.3 Editing the model.

5.1 Basic commands for creating 2D-drawings in AutoCAD

Basic controls 2D AutoCAD

Start Drawing button to create a new drawing (Fig. 5.1).

The main window of the program is shown in Figure 5.2.

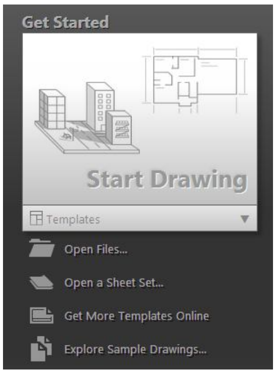


Figure 5.1 – Start Drawing button

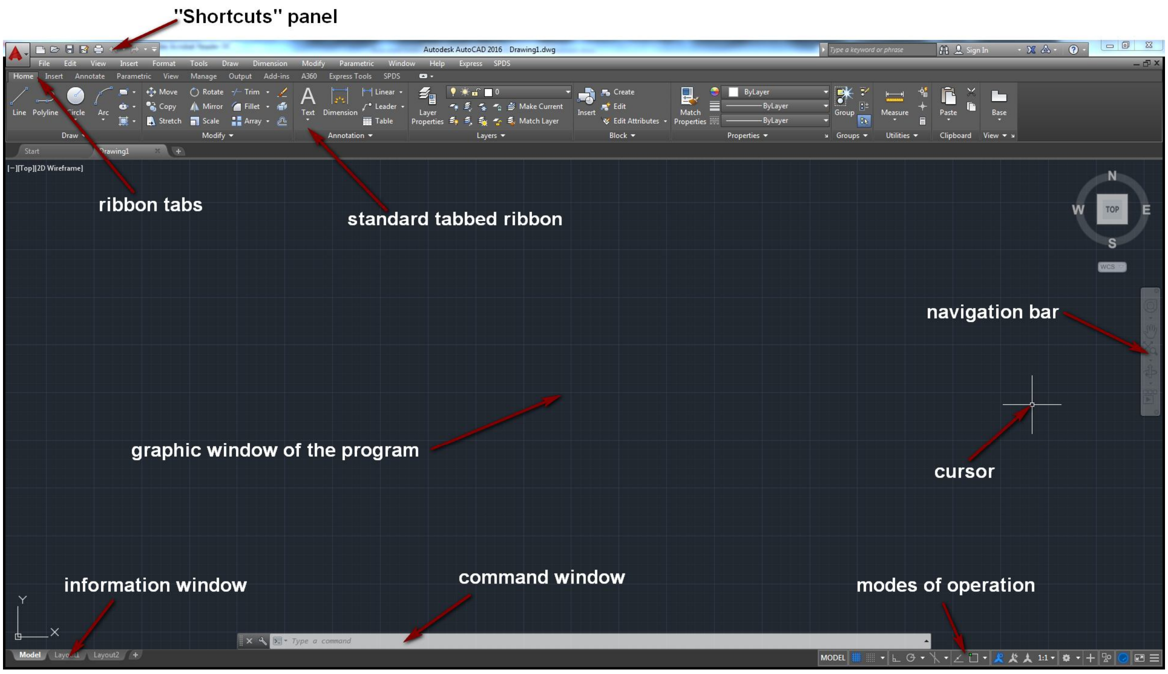


Figure 5.2 – Main window

AutoCAD includes a standard tabbed ribbon across the top of the drawing area. You can access nearly all the commands from the Home tab (Fig. 5.3).

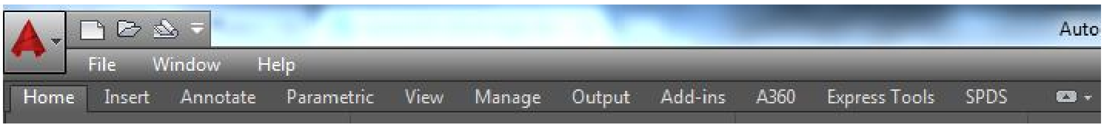


Figure 5.3 – Standard ribbon

The Command Window

At the heart of AutoCAD is the Command window, which is normally docked at the bottom of the application window (Fig. 5.4). The Command window displays prompts, options, and messages.

Figure 5.4 – Command window

Notice that as you start to type a command, it is completed automatically. When several possibilities are available such as in the example below, you can make your choice by clicking it or using the arrow keys and then pressing Enter or the Spacebar.

New Drawings

Click New (Fig. 5.5) to choose from several drawing template files:

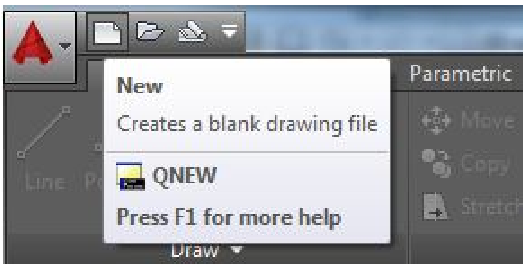


Figure 5.5 – New button of standard ribbon

For metric units that assume your units are millimeters, use acadiso.dwt or acadltiso.dwt (Fig. 5.6).

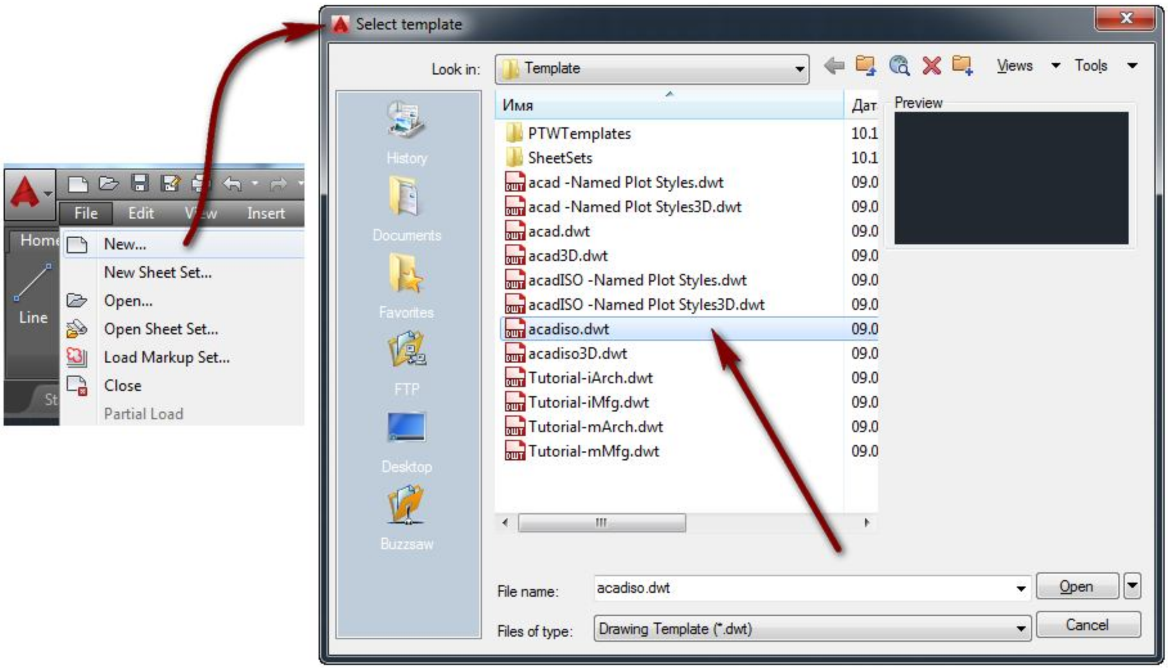


Figure 5.6 – Template files

Units

When you first start a drawing, you need to decide what the length of one unit represents. UNITS command lets you control several unit display settings including the following (fig. 5.7): format (or type), for example, a decimal length of 6.5 can be set to display as a fractional length of 6-1/2 instead; precision, for example, a decimal length of 6.5 can be set to display as 6.50, 6.500, or 6.5000.

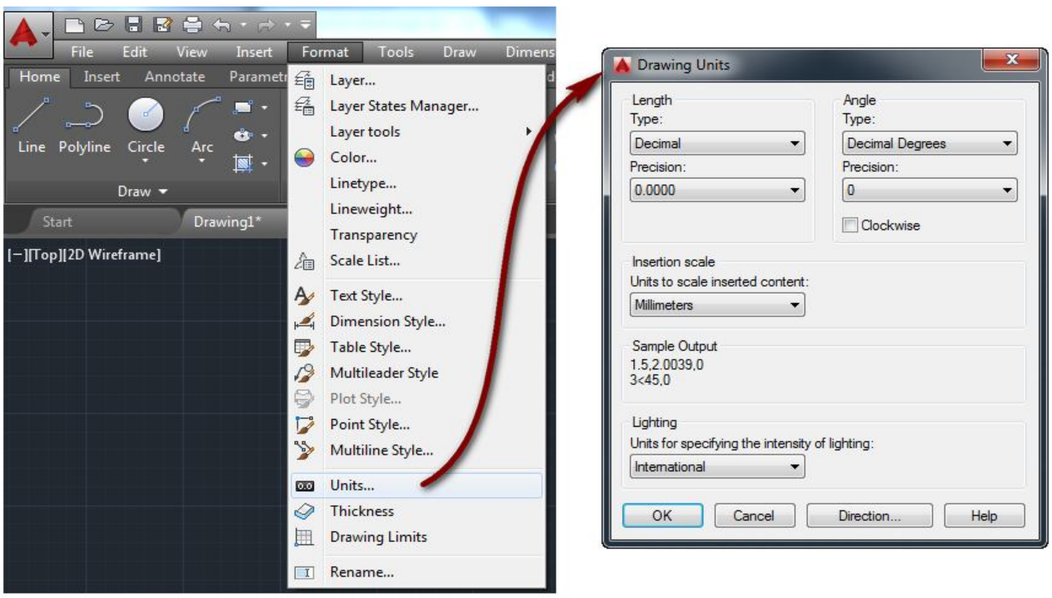


Figure 5.7 – UNITS command

Model Scale

Always create your models at full size (1:1 scale). The term model refers to the geometry of your design. A drawing includes the model geometry along with the views, notes, dimensions, callouts, tables, and the title block displayed in the layout.

You can specify the scaling that is necessary to print a drawing on a standard-sized sheet later, when you create the layout.

General recommendations

1. To open Help with information about the command in progress, simply press F1.

2. To repeat the previous command, press Enter or the Spacebar.

3. To see various options, select an object and right-click, or right-click a user interface element.

4. To cancel a command in progress or if you ever feel stuck, press Esc. For example, if you click in the drawing area before entering a command, you will see something like the following.

Geometry

Create basic geometric objects such as lines, circles and others. If you want to simplify the display while you create geometric objects, press F12 to turn off dynamic input.

Lines

To draw a line, click the Line tool (Fig. 5.8).

Notice the prompt in the Command window for a point location (Fig. 5.9).

Figure 5.9 – Command window directive

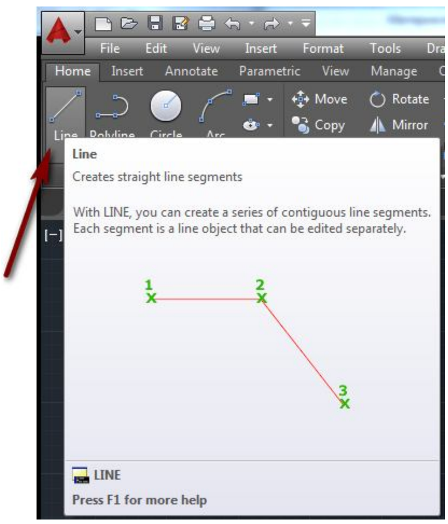


Figure 5.8 – Line tool

To specify the starting point for line, you would type in the coordinates 0, 0. It is a good idea to locate one corner of your model at 0,0, which is called the origin point.

After you specify the next point, the LINE command automatically repeats itself, and it keeps prompting you for additional points. Press Enter or the Spacebar to end the sequence.

To turn off the grid display, press F7. Even with the grid turned off, you can force your cursor to snap to grid increments by pressing F9.

Circles

The default option of the CIRCLE command requires you to specify a center point and a radius (Fig. 5.10).

The other circle options are available from the options menu (Fig. 5.11).

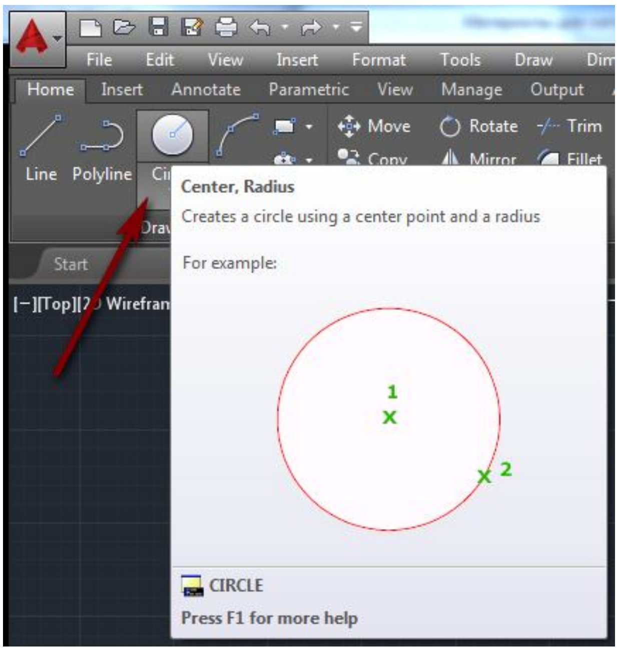


Figure 5.10 – Circle button

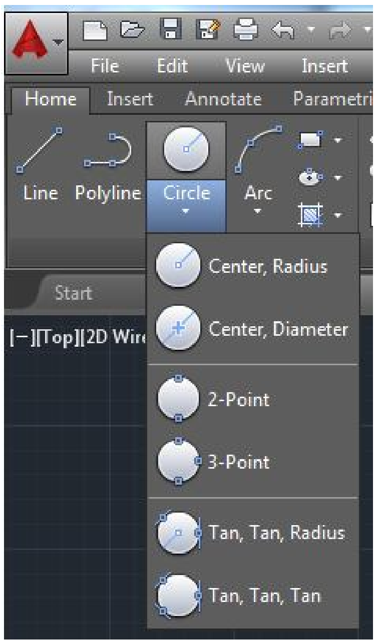


Figure 5.11 – Circle drop-down

Polylines and Rectangles

A polyline is a connected sequence of line or arc segments that is created as a single object (Fig. 5.12).

Polylines can have a constant width or they can have different starting and ending widths. After you specify the first point of the polyline, you can use the Width option to specify the width of all subsequently created segments. You can change the width value at any time, even as you create new segments (Fig. 5.13).

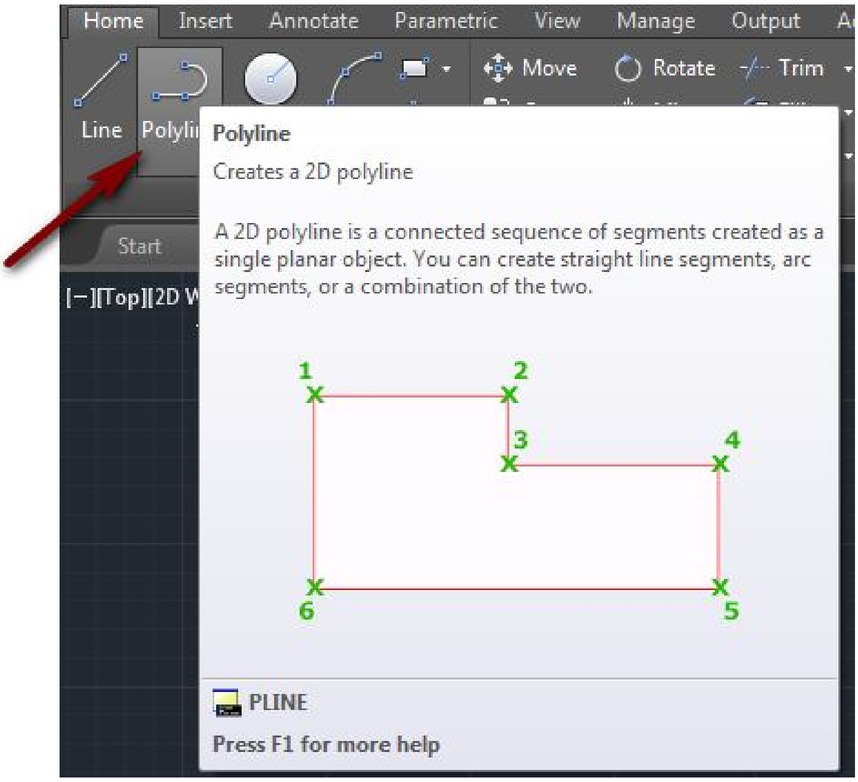


Figure 5.12 – Polyline button

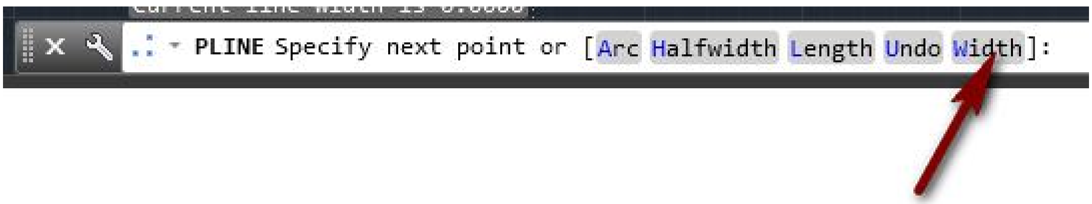


Figure 5.13 – Polyline width

Polylines can have different starting and ending widths for each segment as shown here (Fig. 5.14):

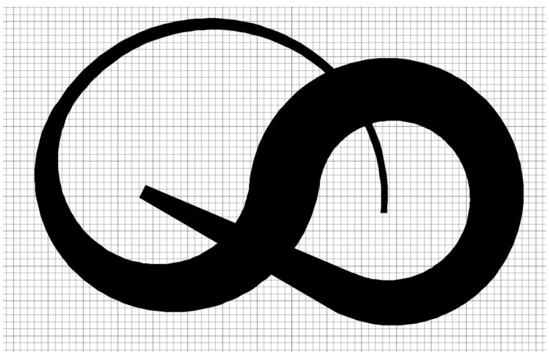


Figure 5.14 – Polylines of different widths

A fast way to create closed rectangular polylines is to use the RECTANG command (Fig. 5.14). Simply click two diagonal points for the rectangle as illustrated. If you use this method, turn on grid snap (F9) for precision.

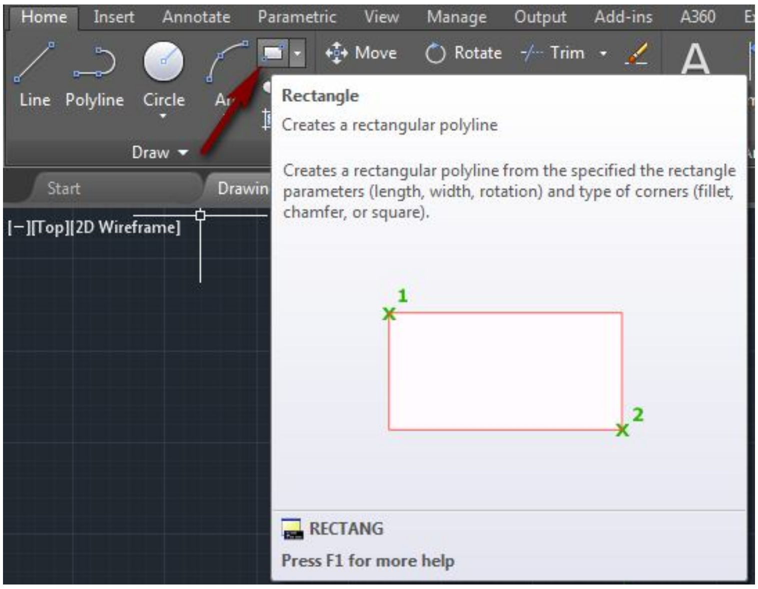


Figure 5.14 – Rectangle button

Hatches and Fills

In AutoCAD, a hatch is a single, compound object that covers a specified area with a pattern of lines, dots, shapes, a solid fill color, or a gradient fill (Fig. 5.15).

When you start the HATCH command, the ribbon temporarily displays the Hatch Creation tab. On this tab, you can choose from more than 70 hatch patterns, along with many specialized options (Fig. 5.16).

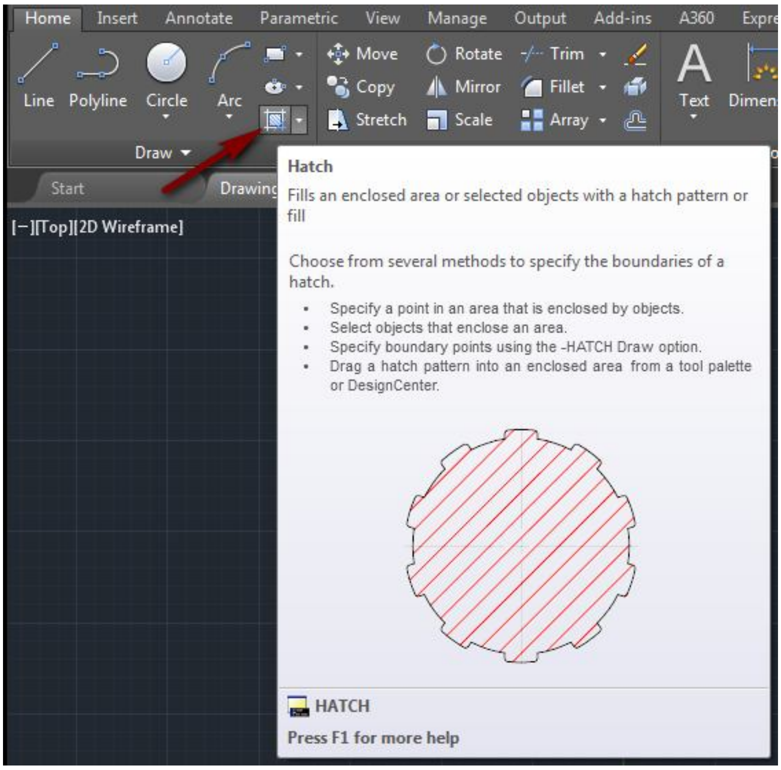


Figure 5.15 – Hatch button

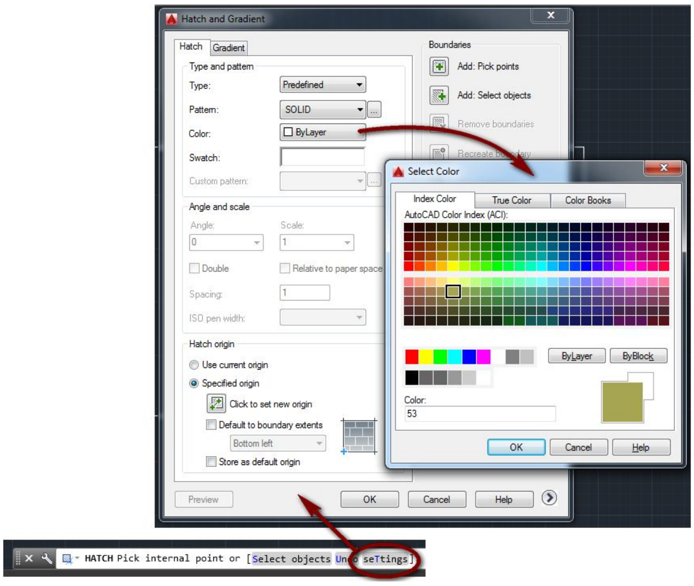


Figure 5.16 – Hatch button

The simplest procedure is to choose a hatch pattern and scale from the ribbon, and click within any area that is completely enclosed by objects. You need to specify the scale factor for the hatch to control its size and spacing.

After you create a hatch, you can move the bounding objects to adjust the hatch area, or you can delete one or more of the bounding objects to create partially bounded hatches.

If an area is not completely enclosed, red circles display to indicate places to check for gaps. Enter REDRAW in the Command window to dismiss the red circles (Fig. 5.17).

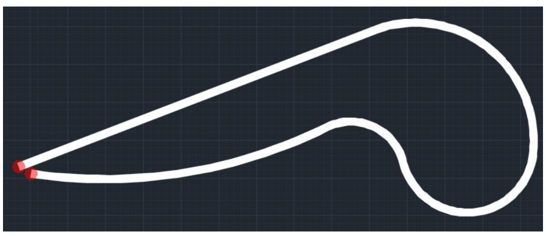


Figure 5.17 – Red circles to indicating a gap

Layers

When a drawing becomes visually complex, you can hide the objects that you currently do not need to see.

You gain this level of control by organizing the objects in your drawing on layers that are associated with a specific function or a purpose. It might be helpful to think of layers as clear plastic sheets (Fig. 5.18):

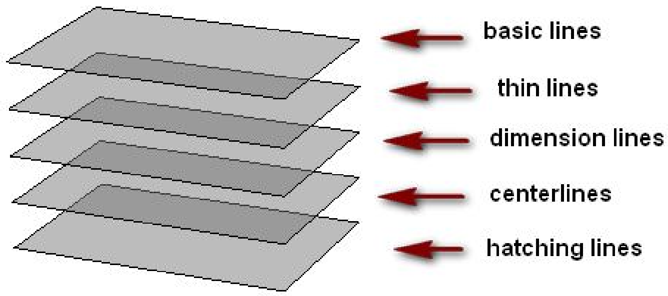


Figure 5.18 – Example of setting layers

With layers, you can:

- associate objects by their function or location;
- display or hide all related objects in a single operation;
- enforce line type, color, and other property standards for each layer;
- resist the temptation to create everything on one layer. Layers are the most important organizing feature available in AutoCAD drawings.

Layer Controls

To see how a drawing is organized, use the LAYER command to open the Layer Properties Manager. You can either enter LAYER or LA in the Command window, or you can click the Layer Properties tool on the ribbon (Fig. 5.19).

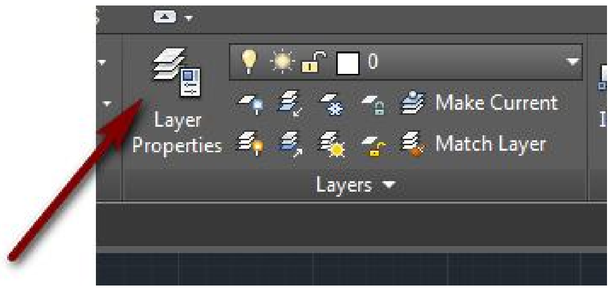


Figure 5.19 – Layer Properties

Practical Recommendations:

1. Layer 0 is the default layer that exists in all drawings and has some esoteric properties. Instead of using this layer, it's best to create your own layers with meaningful names.

2. Any drawing that contains at least one dimension object automatically includes a reserved layer named Defpoints.

3. Create a layer for behind-the-scenes construction geometry, reference geometry, and notes that you usually do not need to see or print.

4. Create a layer for layout viewports. Information about layout viewports is covered in the Layouts topic.

5. Create a layer for all hatches and fills. This lets you to turn them all on or off in one action.

Solid 3D model consists of some 3D elements formed from faces, edges, vertexes and planes. 3D solid objects can start from basic primitives, or from extruded, swept, revolved, or lofted profiles. You can combine these using Boolean operations.

5.2 Basic commands for creating 3D-model in AutoCAD

Basic controls 3D AutoCAD

Main window of AutoCAD program for 3D-modelihg is illustrated in Figure 5.20.

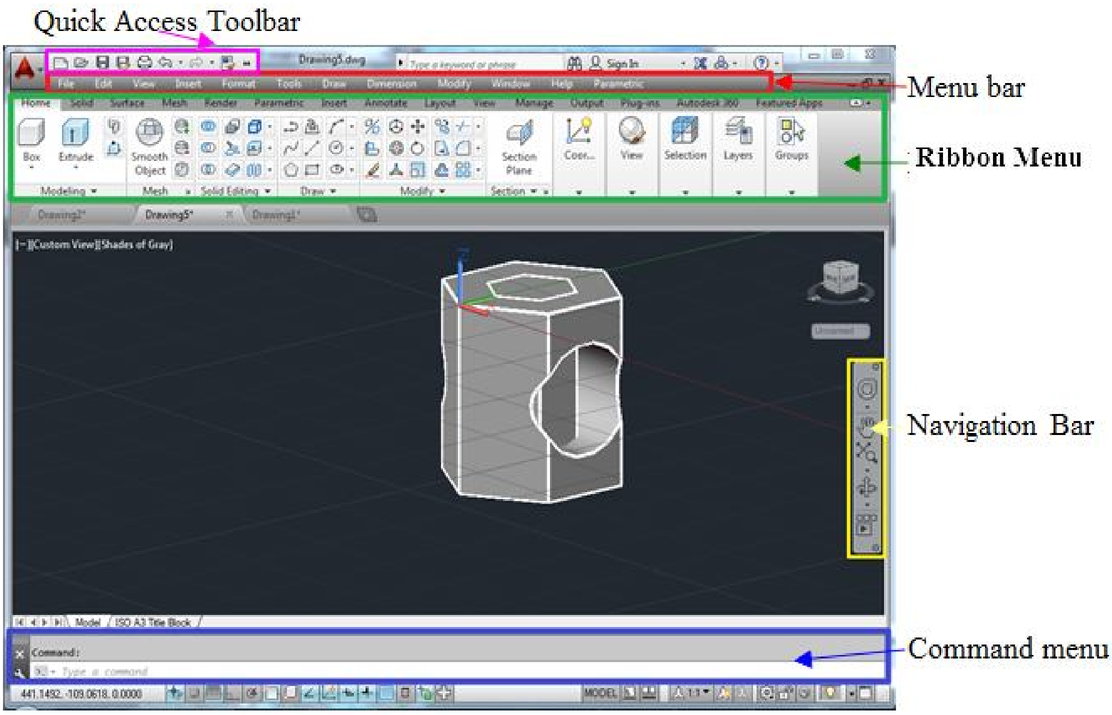


Figure 5.20 – Main window of AutoCAD program 3D mood

In the **Quick Access Toolbar** you should select the 3D Modeling mode (Fig. 5.21).

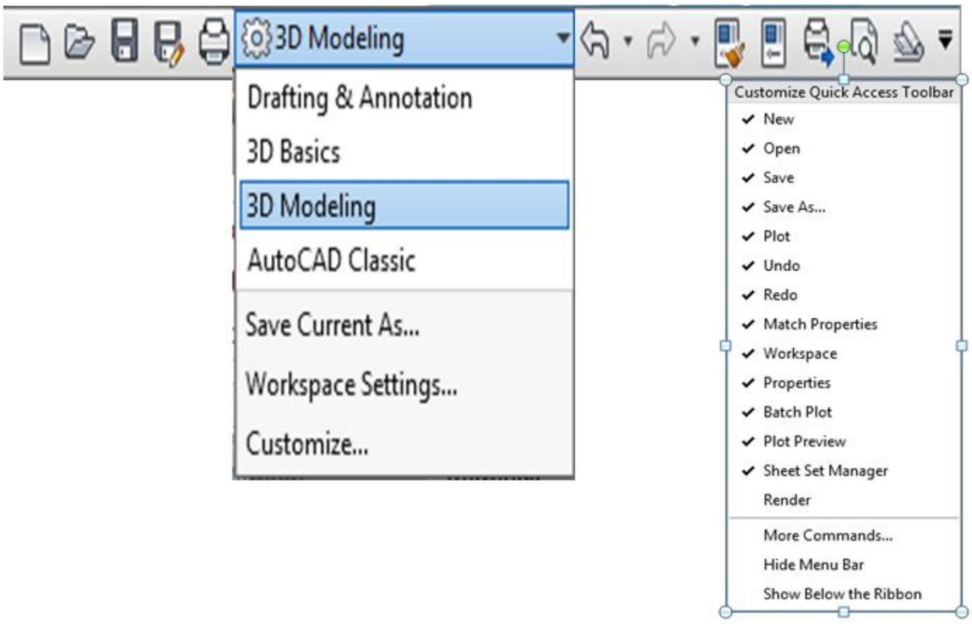


Figure 5.21 – Quick Access Toolbar

Menu Bar consists from tabs: file, edit, view, insert, format, tools and draw (Fig. 5.22).

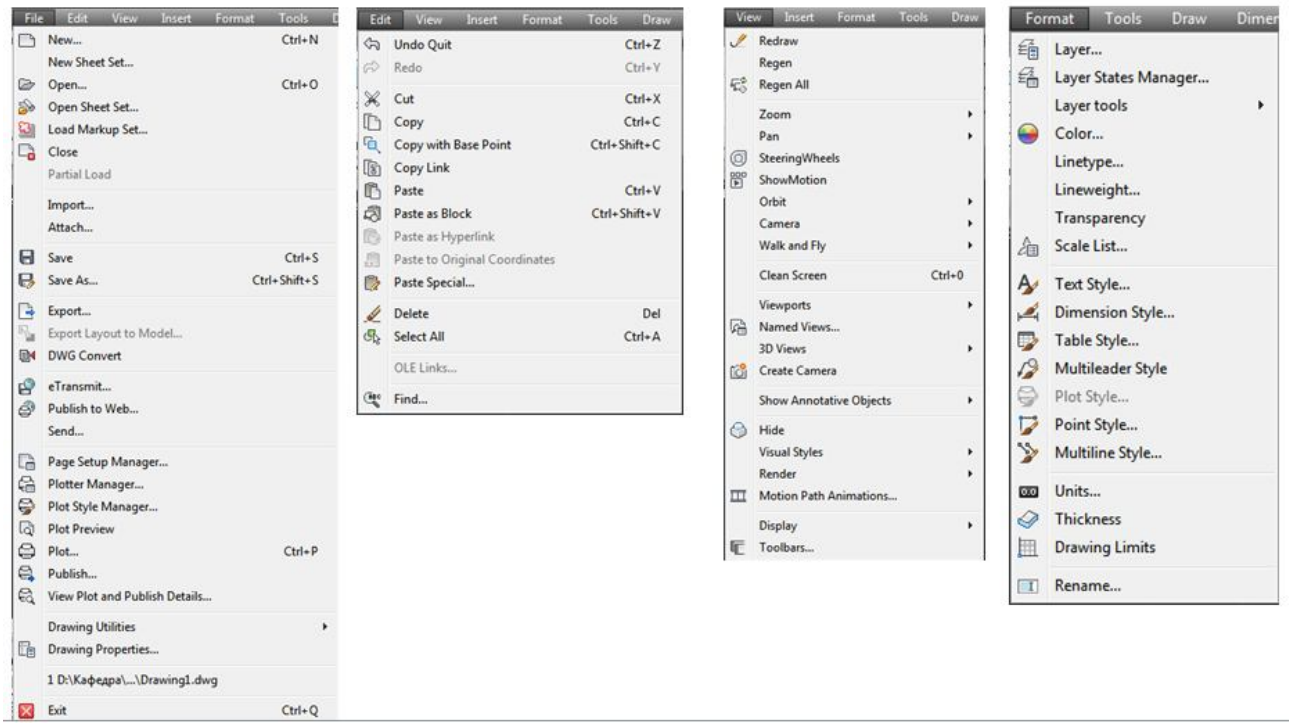


Figure 5.22 – Tabs of Menu Bar

Ribbon Menu and Panels includ tabs: home, solid, surface, parametric, insert, annotate, etc (Fig. 5.23). The ribbon is composed of a series of tabs, which are organized into panels that contain many of the tools and controls available in toolbars. Some ribbon panels provide access to a dialog box related to that panel.

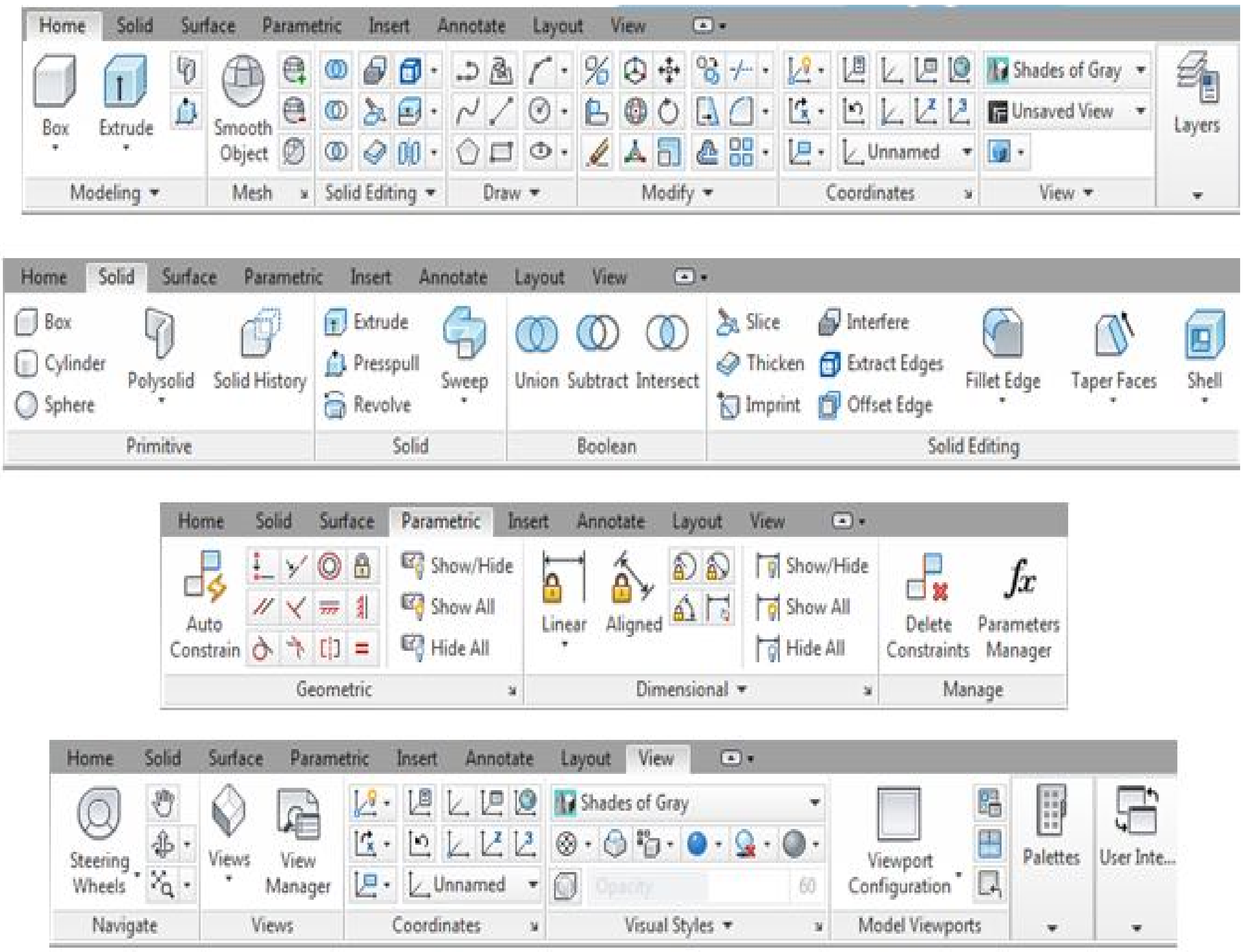


Figure 5.23 – Ribbon Menu and Panels

The *Navigation Bar* is a user interface element where you can access both unified and product-specific *navigation* tools (Fig. 5.24).

The AutoCAD **Command Window** offers efficient keystroke access to commands and system variables. You can even use it to find other content such as blocks, hatch patterns, and layers (Fig. 5.25).

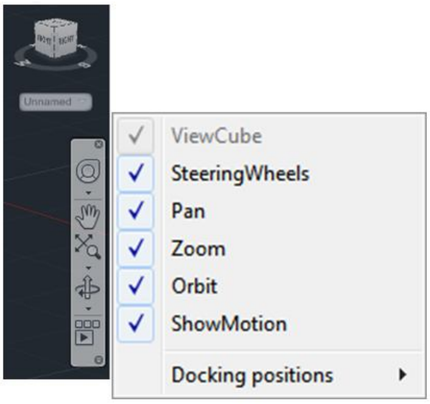


Figure 5.24 – Navigation Bar

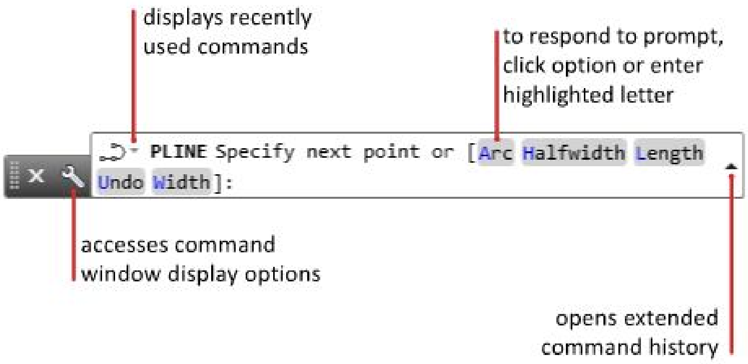


Figure 5.25 – Command Window

5.3 Commands for Creating Primitive 3D Solids

AutoCAD 3D modeling allows you to create drawings using solid, surface, and mesh objects. Solid, surface, and mesh objects offer different functionality, that, when used together, offer a powerful suite of 3D modeling tools. You can then convert the model to a surface to take advantage of associativity and NURBS modeling.

Box 3D-model

Creates a box with length, width, and height values you specify. The length corresponds to the X axis, the width to the Y axis, and the height to the Z axis.

Entering a positive value draws the height along the positive Z axis of the current UCS. Entering a negative value draws the height along the negative Z axis.

The base of the box is always drawn parallel to the XY plane of the current UCS (work plane). The height of the box is specified in the Z-axis direction. You can enter both positive and negative values for the height (Fig. 5 26).

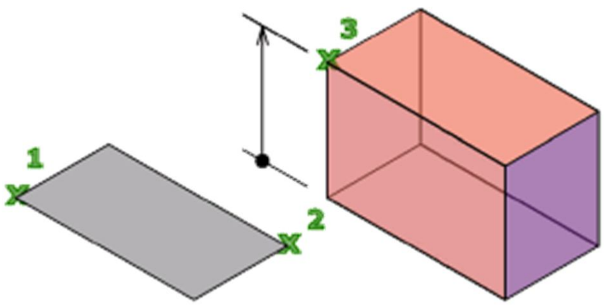


Figure 5.26 – Box

Cone 3D-model

Creates a 3D solid with a circular or elliptical base that tapers symmetrically to a point or to a circular or elliptical planar face. You can control the smoothness of 3D curved solids, such as a cone, in a shaded or hidden visual style with the FACETRES system variable (Fig. 5.27).

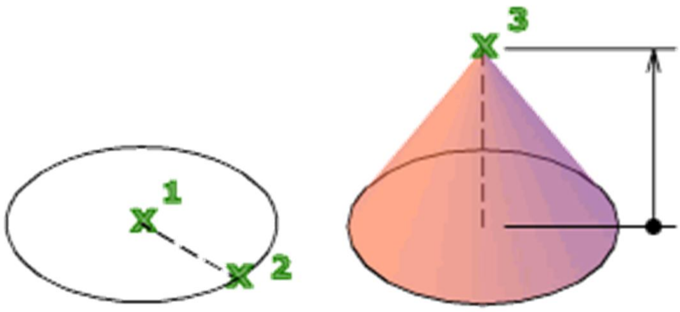


Figure 5.27 – Cone

Use the Top Radius option to create a cone frustum.

Initially, the default base radius is not set to any value. During a drawing session, the default value for the base radius is always the previously entered base radius value for any solid primitive.

Cylinder 3D-model

In Figure 5.28, the cylinder was created using a center point (1), a point on the radius (2), and a point for the height (3). The base of the cylinder is always on a plane parallel with the workplane. You can control the smoothness of curved 3D solids, such as a cylinder, in a shaded or hidden visual style with the FACETRES system variable.

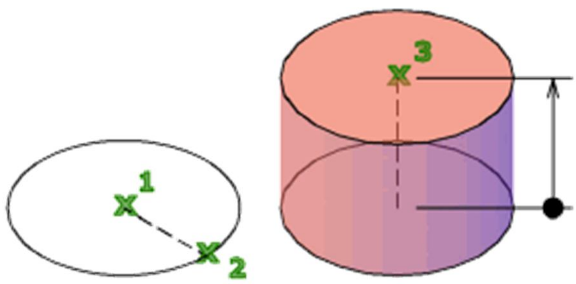


Figure 5.28 – Cylinder

During a drawing session, the default value for the base radius is always the previously entered base radius value.

Polysolid 3D-model

You can create walls with straight and curved segments of constant height and width (Fig. 5.29).

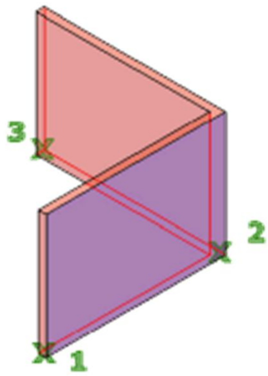


Figure 5.29 – Polysolid

With the POLYSOLID command, you can convert an existing line, 2D polyline, arc, or circle to a solid with a rectangular profile. A polysolid can have curved segments, but the profile is always rectangular by default.

You can draw a solid with POLYSOLID just as you would a polyline. The PSOLWIDTH system variable sets the default width for the solid. The PSOLHEIGHT system variable sets the default height for the solid.

Pyramid 3D-model

By default, a pyramid is defined by the center of the base point, a point on the middle of the edge, and another point that determines the height (Fig. 5.30).

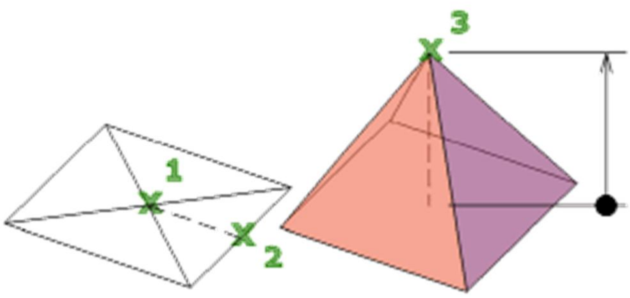


Figure 5.30 – Pyramid

Initially, the default base radius is not set to any value. During a drawing session, the default value for the base radius is always the previously entered base radius value for any solid primitive.

Sphere 3D-model

You can create a sphere by specifying a center point and a point on the radius. You can control the smoothness of curved 3D solids, such as a sphere, in a shaded or hidden visual style with the FACETRES system variable (Fig. 5.31).

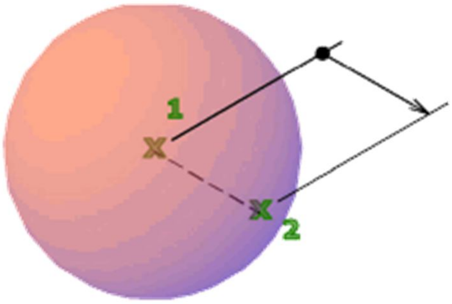


Figure 5.31 – Sphere

Torus 3D-model

You can create a torus by specifying the center, then the radius or diameter of the torus, and then the radius or diameter of the tube that surrounds the torus. You can control the smoothness of curved 3D solids, such as a torus, in a shaded or hidden visual style with the FACETRES system variable (Fig. 5.32).

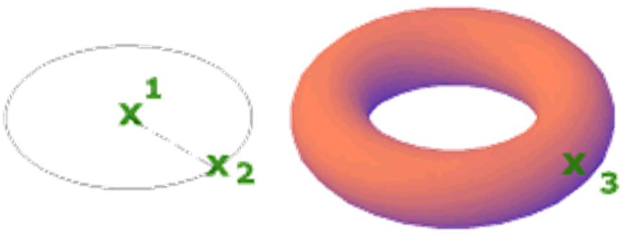


Figure 5.32 – Torus

Wedge 3D-model

The direction of the taper is always in the positive X-axis direction of the UCS (Fig. 5.33).

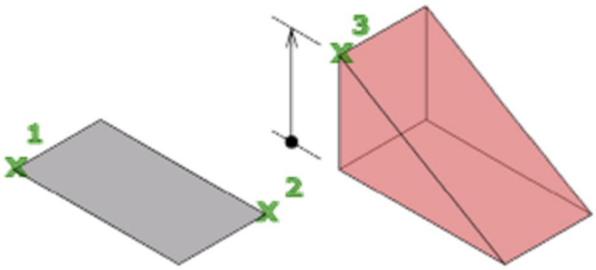


Figure 5.33 – Wedge

Entering a positive value draws the height along the positive Z axis of the current UCS. Entering a negative value draws the height along the negative Z axis.

LECTURE 6 CONSTRUCTION DRAWINGS

6.1 General information about the construction drawings.

6.2 Structural elements of buildings and schemes.

6.3 Graphic images are on the construction drawings. Door and window symbols.

6.1 General information about the construction drawings

Construction drawings are contained from projection images of building objects or their parts and other necessary for their construction data.

Building objects depending on their purpose are subdivided into 4 groups:

- residential and public buildings (civil);
- industrial buildings;
- agricultural buildings;
- engineering structures (bridges, tunnels, overpasses, embankments, etc.).

When performing design and construction plans should be guided by GOSTs ESKD and CDDS (system of design documentation for construction).

Scale drawings are selected in accordance with GOST 2.302–68. For residential and public buildings:

- floor plans, basement, foundations, sections, elevations, installation plans overlap – 1:100, 1:200, 1:500;
- plans sections, fragments of plans, sections and elevations – S 1:50, 1:100;
- products and components – S 1:5, 1:10, 1:20 editing model.

International, or ISO, sheet sizes

Papers manufactured and sold outside of North America are based on 1 square meter.

The International Standards Organization (ISO) system of paper sizes applies to all grades of paper and paper board and consists of five series of sizes: A, RA, SR, B, and C. Within each series, each sheet is twice the size of the next smaller sheet and half the size of the next larger sheet (Fig. 6.1).

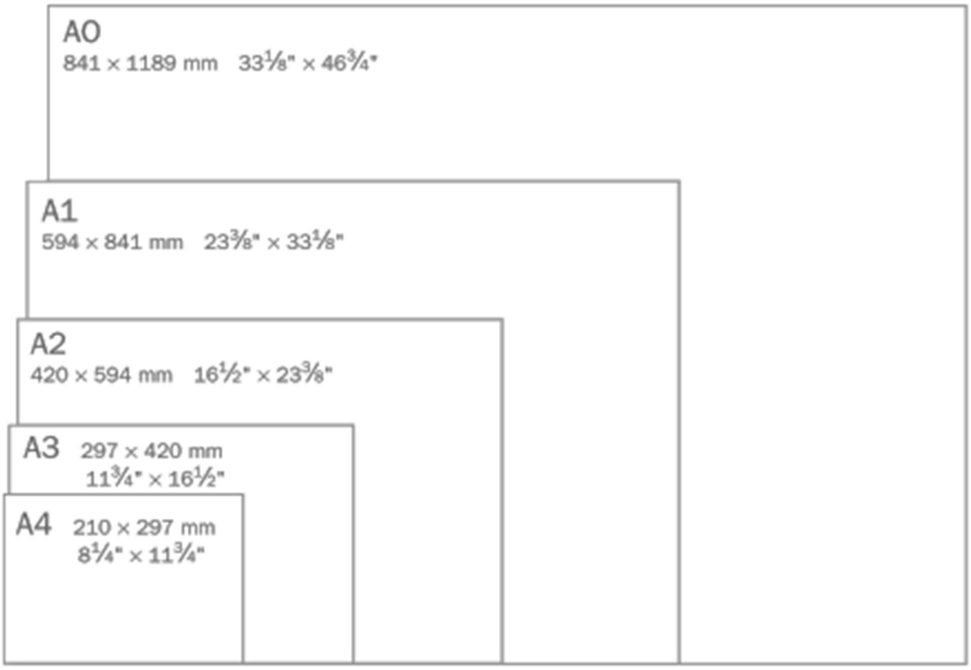


Figure 6.1 – Sheet sizes for construction drawings

Object lines

Object lines are used to show the shape of an object. All visible edges are represented by object lines. All the lines in Figure 6.2 are object lines. Drawings usually include many solid lines that are not object lines, however. Some of these other solid lines are discussed here.

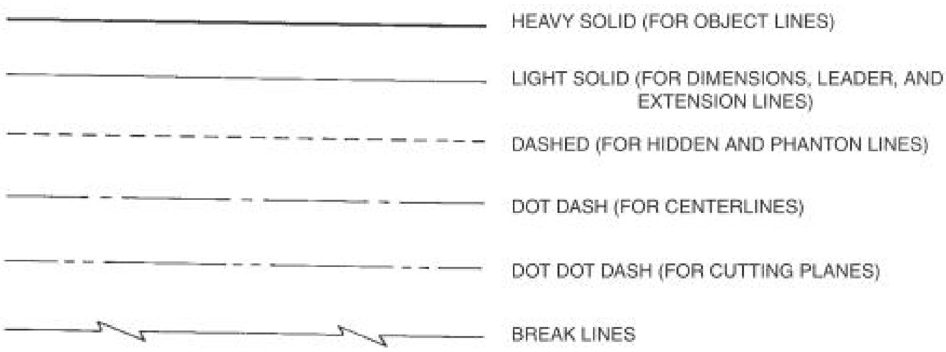


Figure 6.2 – Alphabet of lines

6.2 Structural elements of buildings and schemes

Building objects consist of separate parts – designs. Design teams are composed of individual elements, and monolithic, manufactured on site.

Foundation from wall or under a separate support (column) is called the underground part of the building, through which the load is transferred to the ground. Foundations are tape and columnar. The walls in the building are divided into external and internal. Walls are carriers (which transmit the load on the foundation of its own weight and the weight of ceiling and roof), self-supporting (only its own weight) and wall (hung on the columns consist of individual panels and the weight of the load is transferred to the column).

Partitions – internal walling.

Basement – the lower part of the outer wall, resting on the foundation.

Span – the inner horizontal design that separates the building into floors.

Cover – upper cladding separating the building from the outer space environment.

Roof – top water shut coating layer or roof of the building.

Opening – through a hole in the wall, designed for the windows, doors, gates, etc.

Window unit – sash box.

Door unit – door leaf box. Stairwell – fenced capital (bearing) walls room stairs.

Flight of stairs – ramp stairs with steps (no more than 18 steps).

Staircase – horizontal element stairs between marches. Summary - level floors, intermediate – to move from one to another march.

Rafters – roofing truss structures that represent beams, resting on walls and internal support.

Coordination axis

The construction plan begins with the drawing axis on a number of elements. These axes define the location of the main load-bearing structures and are called coordinating the longitudinal and transverse axes. Distance between axes of the plan is called the step. Step can be longitudinal or transversal.

Coordination axes put phantom lines and indicate brands in the circles of diameter 8–12 mm. For marking to applied Arabic numerals and capital letters. Font size one or two rooms are larger than the font size of numbers.

The figures mark the axis side of the building with a bigger number of axes. The sequence of marks – left-to-right, bottom-up (Fig. 6.3).

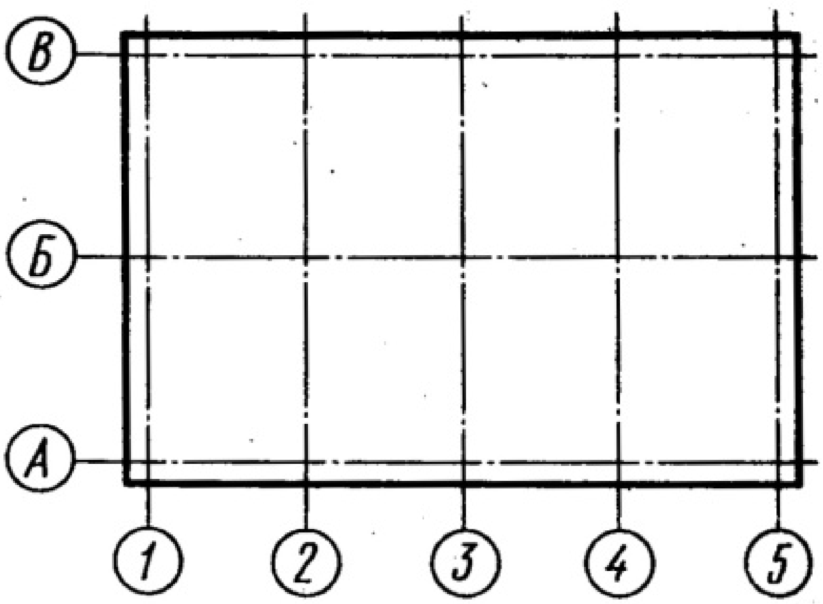


Figure 6.3 – Mark the axis

In buildings with bearing longitudinal and transversal walls binding coordination axes external and internal walls make as follows:

- on beams leaning against walls and internal support:
- inside face of the outer wall is placed on the coordination axis at a distance M or 2M, i.e. 100 or 200 mm (modular binding);
- coordination axis coincides with the inner wall surface (no binding);
- in internal walls coordination axis must coincide with the axis of symmetry walls, except the walls, staircases and walls with ventilation ducts (center binding).

Dimensions on the construction drawings

Dimensions are given for the sizes and locations of all walls, partitions, doors, windows, and other important features. On frame construction, exterior walls are usually dimensioned to the outside face of the wall framing.

Dimensions in mm without affix represent units of measure and applied as closed circuit (Fig. 6.4).

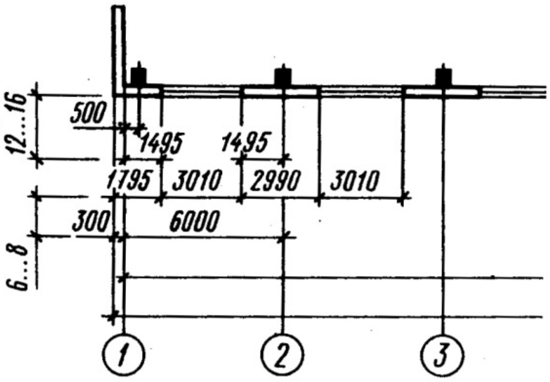


Figure 6.4 – Dimension lines in the drawing

When dimensioning diameters, radii and angles instead of serif put arrows. Mark levels (height, depth) of an element of a building or structure from the indicating any level, taken as zero, is placed on the outrigger lines or contour lines and designated by the symbol (Fig. 6.5).

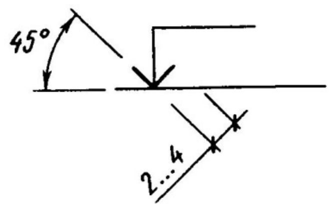


Figure 6.5 – Extension lines in the drawing

Mark indicated in meters with three decimal places. Conditional marks indicate 0.000. The level is below the zero conditional mean minus sign, mark above the zero – unsigned. As a zero mark for buildings usually take the floor level of the first floor. Marks are accompanied by explanatory titles – LCP (the level of the clean floor), GL (ground level).

On the plans, if necessary, marks indicate with a plus sign.

On the plans of the slope direction of the plane cursor over which (if needed) write down the value of the slope (Fig. 6.6).

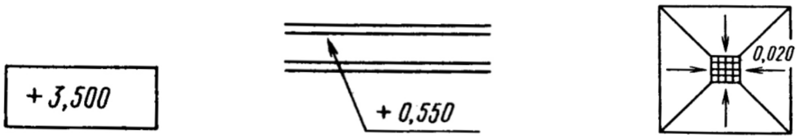


Figure 6.6 – Marks on the plane

Construction drawings of buildings and constructions consist of the General rules rectangular projection on the basic plane projections. Images of the buildings have their own names.

6.3 Graphic images on the construction drawings. Door and window symbols

Door and window symbols show the type of door or window used and the direction the door or window opens. There are three basic ways for household doors to open – swing, sliding or fold shown in Figure 6.7. Within each of these basic types there are variations that can be readily understood from their symbols. The direction a swing-type door opens is shown by an arc representing the path of the door.

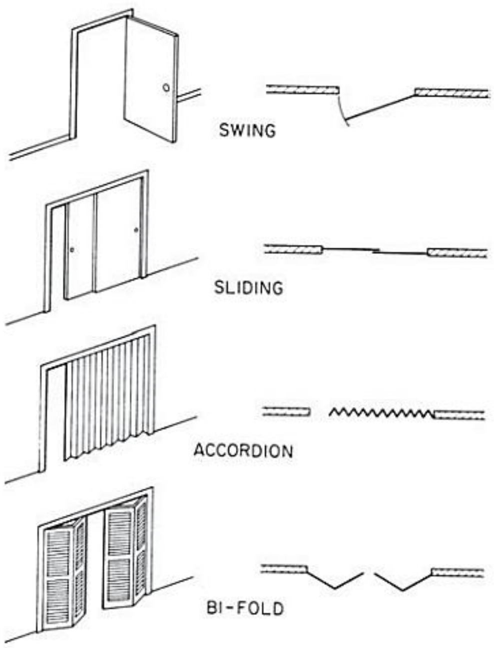


Figure 6.7 – Types of doors and their plan symbols

There are seven basic types of windows. They are named according to how they open (Fig. 6.8). Other symbols on the drawings shown in table 6.1.

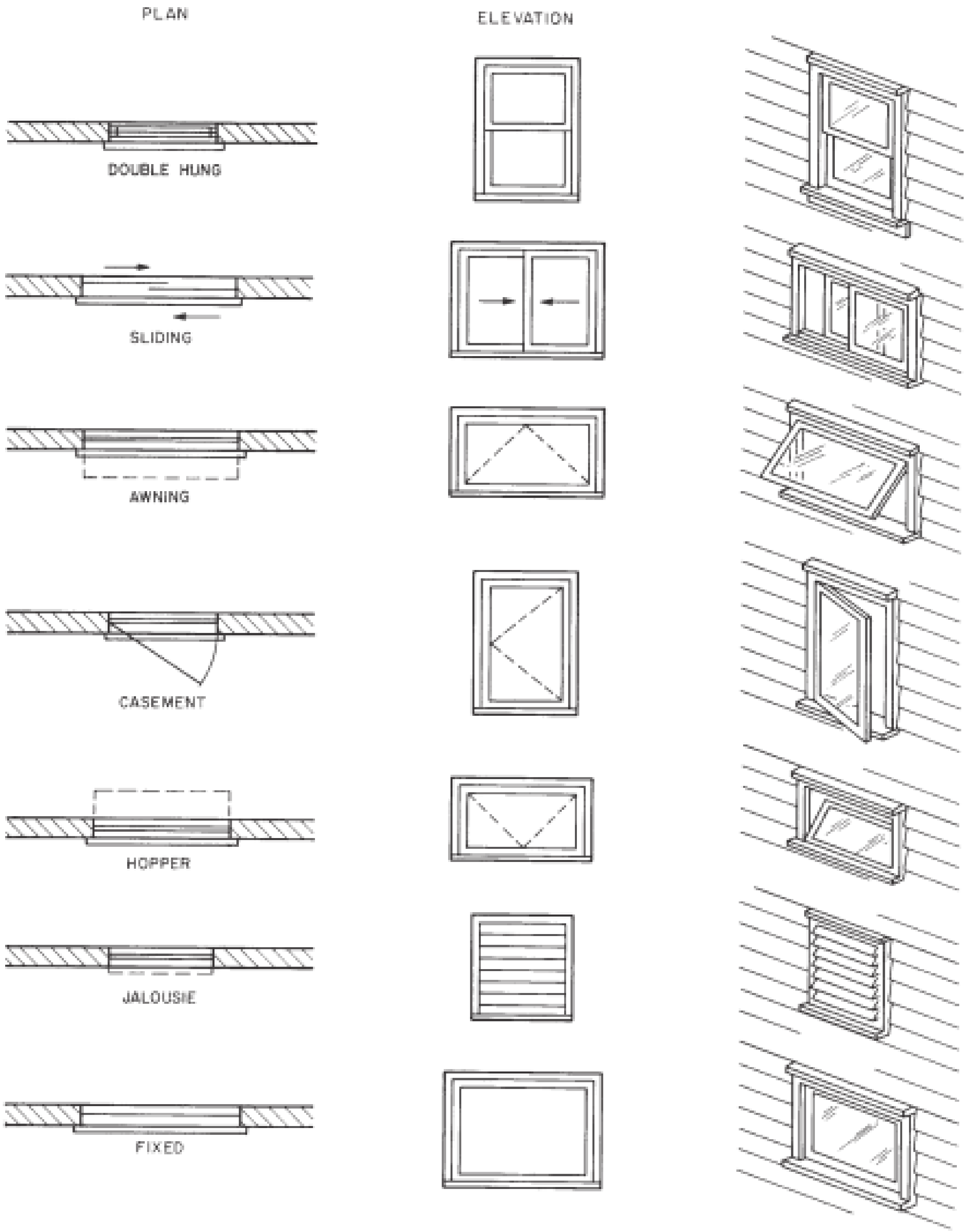
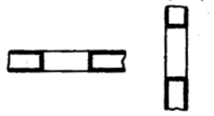
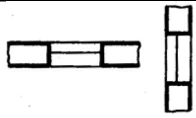
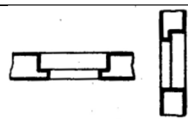
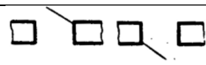
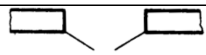
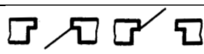
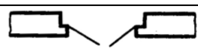
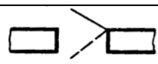
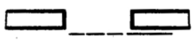
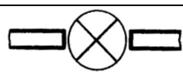
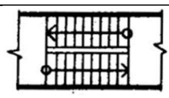
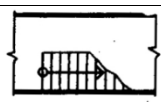
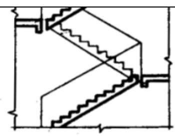
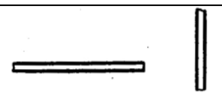
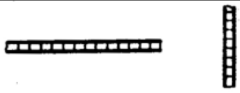
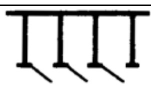
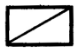
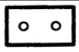
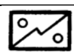
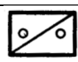
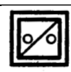
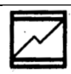


Figure 6.8 – Types of windows

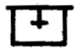
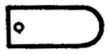
Table 6.1 – Symbols on the drawings

Name	Image
1	2
Windows	
1 Opening without-quarters of a wall or partition Window	
2 Window opening without quarters	
3 Window opening with quarters	
Doors (gates)	
4 The door from the door opening without quarters	
5 The door from the door opening without quarters	
6 The door from the door opening with quarters	
7 The double door opening of the quarters	
8 The door from swaying canvas	
9 The sliding door	
10 Revolving door	
Stairs	
11 Ladder in terms of upper marsh	
12 Stairs in the plan – interim marches	
13 Ladder in terms of lower marsh	
14 Ladder in terms of scale 1:100 and smaller	

Continue of the table 6.1

1	2
Partitions, cabins, cupboards	
15 The partition wall in plan and section	
16 Partition team shield plan	
17 Wall of glass in the plan and the section	
18 Cockpit shower in the plan	
19 Cab latrines in terms	
20 Built-in wardrobe in the plan	
Vents, ducts in the walls	
21 The hole rectangular, round	
22 Chimney in the plan	
23 Channel ventilation in the plan	
Ovens, stoves, refrigerators	
24 Furnace heating	
25 Furnace heating stationary gas	
26 Stove	
27 Fixed electric stove	
28 Plate fixed on gas	
29 Stove, portable gas	
30 Stove portable electric	
31 Electric refrigerator	

Ending of the table 6.1

1	2
Sanitary-engineering devices	
32 Sink	
33 The kitchen sink	
34 Washbasin	
35 Bath	
36 Bidet	
37 The floor toilet	
38 The wall-mounted urinal	

LECTURE 7 CONSTRUCTION DRAWINGS AND ELEMENTS OF THE BUILDING

7.1 Drawings of the building plan.

7.2 Section drawings.

7.3 Elevation drawings.

7.1 Drawings of the building plan

The plan of the building is called the image of the building, mentally dissected by a horizontal plane at the level of window and door openings (about 1 m) and projected onto the horizontal plane of projection. The plan shows what is clipping plane and what is underneath it.

On the plan of the building show window and door openings, the location of the stairs, partitions and capital walls, built-in cabinets, sanitary-technical equipment end other. The plan placed under the elevation in the flat connection with it.

The position of all structural elements is determined by reference to the coordination axes.

Outside the building contour put the size of window and door openings «in the light» and spaces between them (the first dimensional chain), coordination between axles (second dimensional chain) and the axis (the third dimensional chain).

Internal dimensions of premises, thickness of walls and partitions should be put on internal dimensional chains. They spend at least 8...10 mm from a wall or partition. Also bind all the inner main walls to the axes.

Floor space is put down in the lower right corner of the plan of the premises in square meters without designation of units with two decimal places and a bar beneath.

The plans show what direction the door opens. Exterior doors from the street to the house should open outwards, and the door from the stairs to the apartment is inside the apartment. Opening the other doors is depended on the convenience of planning and operation.

Brand of Windows and external doors should be put on the outer side of the wall. On the open plan line shows the clipping plane for the corresponding section (Fig. 7.1).

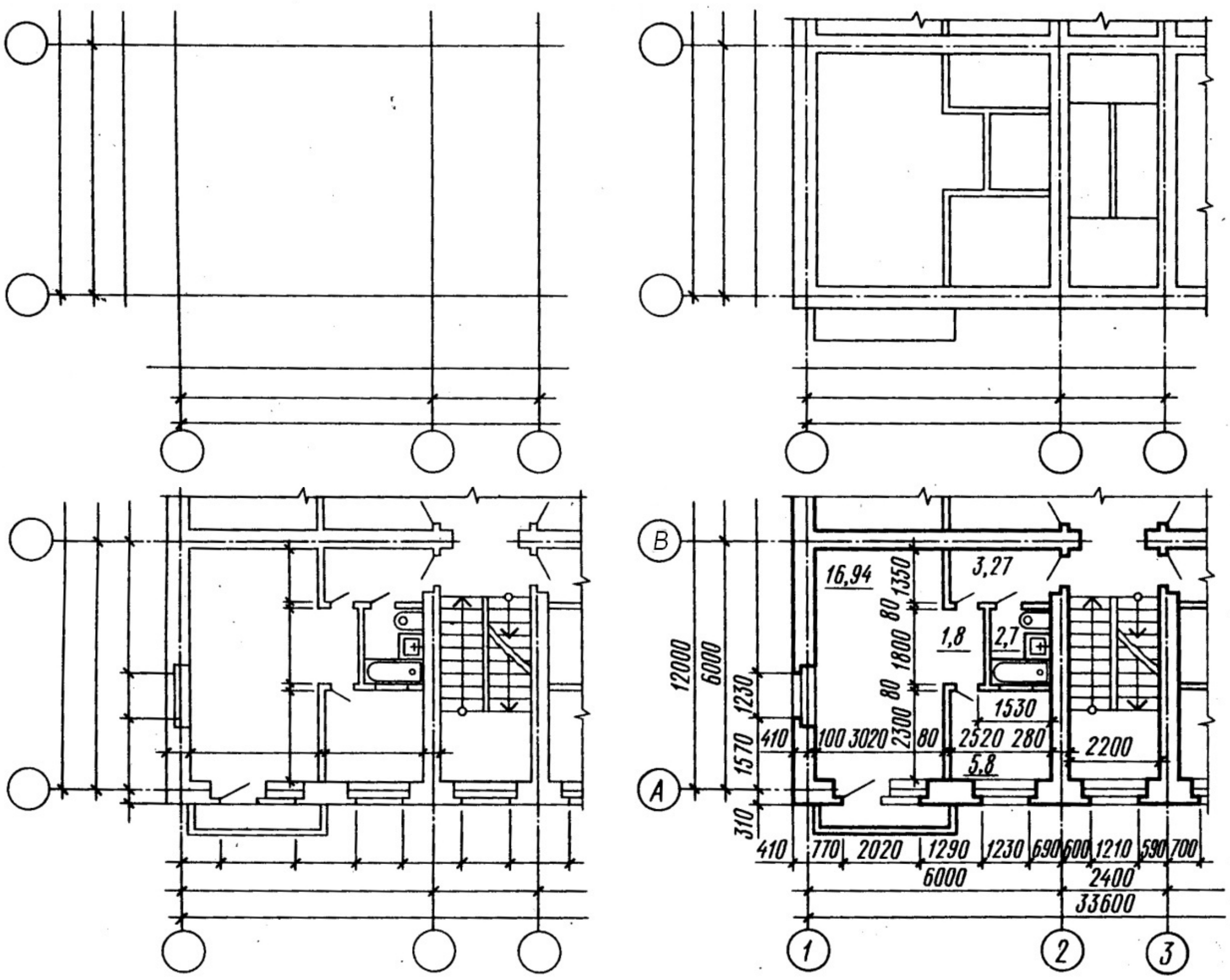


Figure 7.1 – The sequence drawing of the building plan

A building plan is drawn in the following order:

- conduct longitudinal and transversal coordination axis;
- draw all external and internal walls, partitions and columns;
- produce a breakdown of window and door openings in the external and internal walls and partitions, conditionally show opening doors;
- draw stairs, sanitary appliances, built-in wardrobes, mezzanine, balcony fences and other elements;

- put the necessary external and dimension lines show the cutting line;
- put down all sizes, make appropriate titles, check the drawing;
- make a final stroke.

Contours of cuts and sections operate continuous main line. Elements that do not fit in the plane of section are performed by a thin line.

7.2 Section drawings

A sectional image of the building is called, mentally dissected vertical plane and projected onto the projection plane.

Direction of the cutting plane is marked on the ground floor open plan line with arrows at the ends, showing the direction of gaze. About the shooter put Arabic numerals or lowercase, but in the context of making the inscription type: Section 1–1.

On the cuts visible contour lines that do not fit in the plane of section, perform a continuous thin line.

On sections focal axis endure down and affix label sizes between adjacent axes.

Position of structural elements height is determined by the elevations and dimensions, which appears on the remote lines levels of the respective elements.

Inside the cut applied height floors, doors and windows, as well as elevations and floor levels stairwells.

For installation of staircases and platforms is a section along the stairs. The section plane is held by fellow flight of stairs to the observer.

On the exterior side of the cut at a distance of 12–15 mm spend dimensional chain, determines the size of the window openings and piers, cap, outside the doorway. At a distance of 10–15 mm from the chain cause elevations of the ground level and the top of the walls, shelves turned out.

Also the marks are applied to the floor stairwell in the vestibule, entrance areas – one step above the sidewalk. The level of these sites increases towards a flight of stairs, so that rainwater does not fall into the stairwell.

Industrial buildings in sections depict not all items in the cutting plane, but only those that are in close proximity.

The section drawings are shown in Figure 7.2.

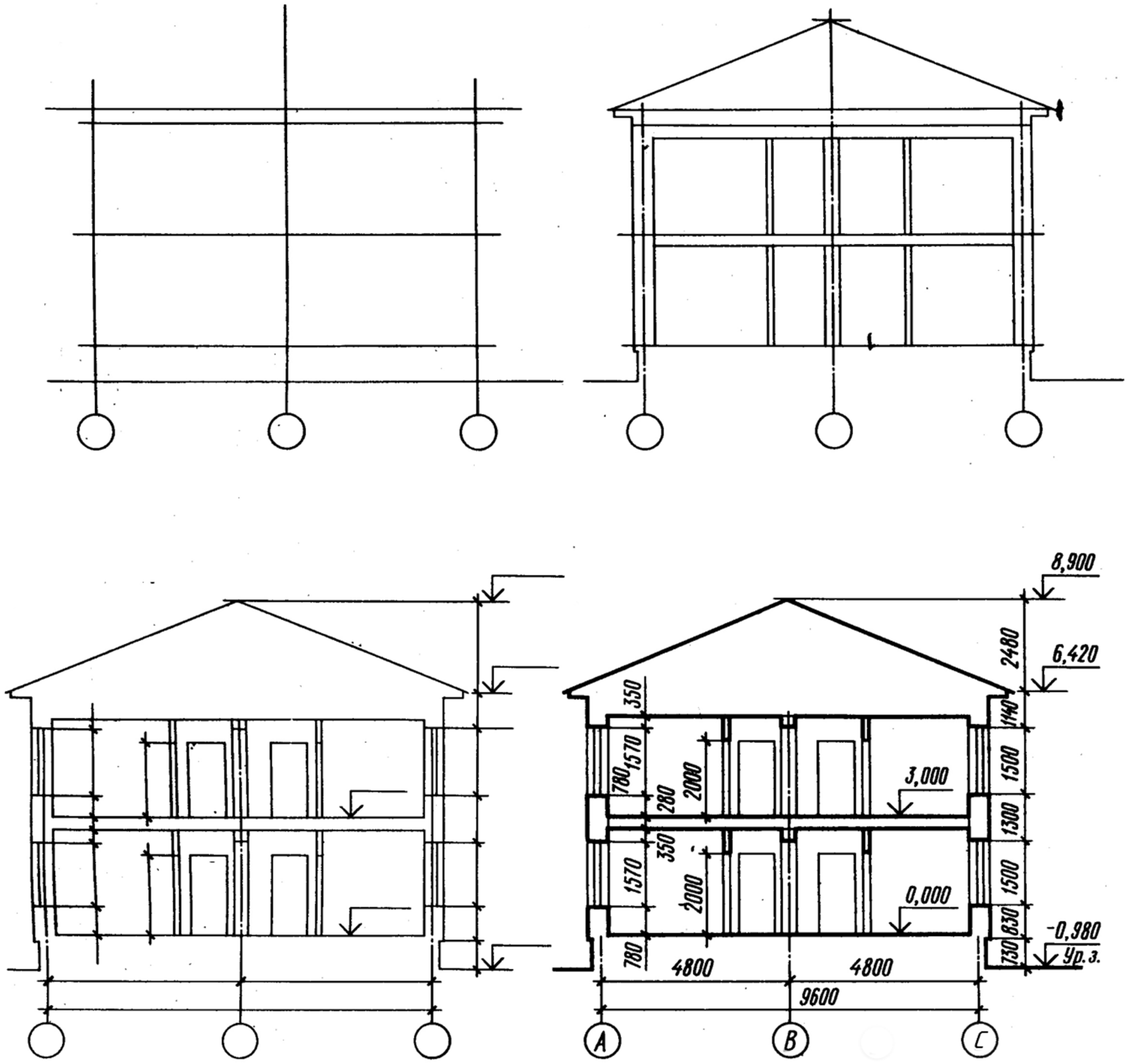


Figure 7.2 – Section drawings

A building section is drawn in the following order:

- draw coordination axis main load-bearing structures and perpendicular to them, horizontal lines of levels: land surfaces, floor all floors and the attic floor and the top of the cornice;
- contours applied exterior and interior walls, partitions, caught in the cut, as well as the height of intercommunication and attic floors and roof ridge is drawn takeaway cornice and plinth, draw the roof slopes;
- scheduled in the exterior and interior walls and partitions of windows and doors, as well as visible doorways and other elements located behind the cutting plane;
- carried outrigger and dimension lines, circles marking axes and signs elevations;
- produce the final stroke, dimensions and elevations make explanatory inscriptions and indicate the name of the section.

7.3 Elevation drawings

Types of buildings in the front, rear, right and left are called elevations. In the name of elevations indicate extreme focal axis. Elevations give an idea of the appearance of the building, its overall shape, size, number of floors, the presence of balconies and loggias.

View of the building from the street called the main elevation, from the yard – yard and side – end.

In the elevation drawings show the location of windows, doors, balconies, door trims, etc. In the large-panel buildings and walls the blocks and the panels are shown. Dimensions are not applied on elevation but only the extreme axis shown on it. The right or left a ground line, the top and bottom openings, eaves, top roof are shown on this drawing.

Elevations are usually performed in scale 1:100, 1:200 (civic buildings) and 1:200, 1:500 (industrial buildings). Complex view elevations are in the fragments in scale 1:10, 1:20.

The elevation drawings are shown in Figure 7.3.

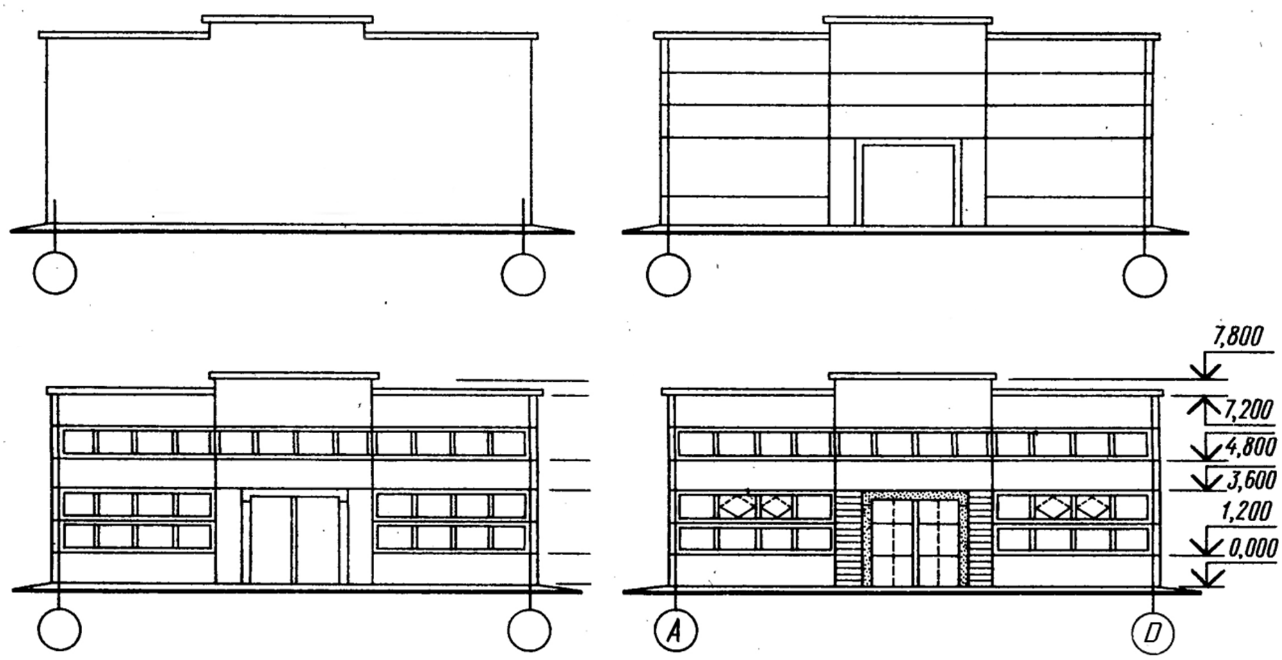


Figure 7.3 – Elevation drawings

A building elevation is drawn in the following order:

- draw the axis and the outline of the building;
- draw the windows and doorways, balconies, canopies plates, cornice and others architectural elements;
- draw the window frames, doors, fences balconies, vents and chimneys on the roof, put down markers icons;
- applied levels of the appropriate heights, marked focal axis;
- after verification of compliance with the plan and make the final circuit.

Draw the main line of the ground. Land line make thickened line that goes beyond the elevation view.On the architectural drawings on walls sometimes show shadows and elements entourage.

Sometimes necessary information can be conveyed without showing the interior construction. A large scale may be all that is needed to show the necessary details.

Many details are best shown by combining elevations and sections or by using isometric drawings.

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КОНСПЕКТ ЛЕКЦІЙ

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